An Assessment of the United States Measurement System:

Addressing Measurement Barriers to Accelerate Innovation

Appendix H

Analysis of Case-Study Measurement Needs: Summary Report

NIST Special Publication 1048



U.S. Measurement System

Measurement Need (MN) Data Book

Prepared by
Energetics Incorporated
for the
National Institute of Standards and Technology

April 2006

Introduction SECTOR CHAPTERS

- 1. Building and Construction
- 2. Chemicals, Industrial Biotechnology, and Continuous Manufacturing
- 3. Defense and Homeland Security (including First Responder)
- 4. Electronics Non-Semiconductor and Information Technology (IT) Hardware
- 5. Electronics Semiconductor
- 6. Energy and Power and Environment
- 7. Healthcare (including Bioimaging)
- 8. Manufacturing (Discrete) and Automotive
- 9. Materials
- 10. Nanotechnology
- 11. Software for Information Technology (IT)
- 12. Assessment of all Economic Sectors/Areas Assessed

Introduction

The U.S. Measurement System (USMS) Measurement Need (MN) Data Book contains a series of correlation tables and distribution charts based on over 300 one-page measurement need summaries developed by NIST for various sectors of the economy as well as technology areas. The supporting data for each table and chart was derived from individual MNs through a "tagging" process designed to gather a consistent set of information from each MN. The tags were developed from the perspective of providing key information about measurement providers, solutions, and barriers, as well as other parameters. Each table and chart provides results for selected tags or sets of tags. The methodology and the set of tags used is discussed in more detail in "An Approach for Inferring the State of the USMS from the MN Analysis, Roadmap Analysis, and USMS Characterization."

It should be noted that for each MN, there are multiple choices for some sets of tags. For example, up to three tags are possible for measurement solutions, measurement barriers, measurement providers, and selected other tags. Consequently, the total number of "hits" in a single chart or table may exceed the number of MNs in that sector. On tables and charts where this occurs, MN Element is used rather than MN on the vertical axis to reflect that multiple tags may be selected for some categories.

The information contained in these tables and charts is integral to the inferential methodology that is being used by NIST to assess the state of the USMS. Different inferences, for example, might be drawn by looking at simple histograms or distributions of tags, or by combining tags in various ways. Both correlation tables and distribution charts may be used to identify and support findings about the USMS, particularly within the sector of interest. The utility of both approaches is outlined below.

Correlation Tables

Correlation tables compare one set of tags with another to help discern synergies, identify areas of greatest emphasis (and those of no interest), and possibly point to key problem areas within a sector or technology. Each table has two sets of parameters being compared or correlated – and these are noted in the title of the table.

Each cell in the table indicates the juncture of two parameters, and the number (if any) in the cell indicates the number times that juncture occurred in the set of MNs analyzed. Cells shaded in blue indicate a higher number of junctures; green shading indicates a lower number. For example, the correlation table for Healthcare comparing Measurement Solution Barriers with Measurement Solutions might have a number of 20 in the blue-shaded cell corresponding to Accuracy (barrier) and Measurement Instrument (solution). This means that 20 MNs were tagged with Accuracy as a barrier and with Measurement Instrument as a solution. This tells us that within the Healthcare sector, accuracy is a primary measurement challenge, and new instrumentation is one of the key solutions.

Correlations may also point out anomalies. For example, if a large number of MNs were tagged with "lack of fundamental knowledge" as a measurement barrier, you would expect that providers of fundamental measurement science or research would emerge as key providers. If this were not the case, it might point to a key finding about how measurement needs are communicated within the USMS.

Distribution Charts

Distribution charts are simple histograms that summarize the number of times a particular tag was selected for the set of MNs in a sector. These provide a good sense of what the key issues are within a sector, and may be used as supporting evidence for an inferential finding. Distribution charts are titled with the primary category of the tags (measurement solution, measurement barrier, etc). All of the distribution charts use vertical bars to display the number of "MN elements" for each tag within the group (shown along the horizontal axis). For example, a histogram for measurement solutions will have 23 tags on the horizontal axis. All tags are represented on the charts, even if none were selected for that group of MNs (zero, or no bar visible).

U.S. Measurement System

Measurement Need (MN) Data Book

Chapter 1. Buildings and Construction

(Includes Residential / Commercial Building, and Civil Infrastructure)

Prepared by
Energetics Incorporated
for the
National Institute of Standards and Technology

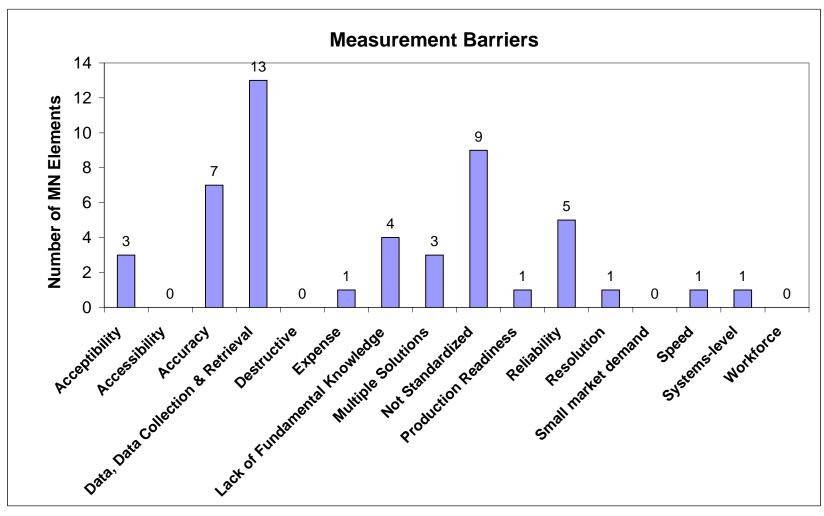
April 2006

Reference List of MN Distribution Charts and MN Correlation Matrices

Distribution	n Charts	Page
Exhibit Num	nber	
1.1	Measurement Barriers (Buildings and Construction)	1
1.2	Solution Providers (Buildings and Construction)	2
1.3	Measurement Solutions (Buildings and Construction)	3
1.4	Measurands (Buildings and Construction)	4
1.5	Current Public/Private R&D Efforts (Buildings and Construction)	5
1.6	Has Measurement Technology (Buildings and Construction)	6
1.7	Stage of Technological Innovation (Buildings and Construction)	7
1.8	Regulation as Driver/Barrier (Buildings and Construction)	8
Correlation	n Matrices	
Exhibit Num	nber	
1.9	Solution Providers – Measurement Barriers (Buildings and Construction)	9
1.10	Measurement Barriers - Measurement Solutions (Buildings and Construction)	10
1.11	Solution Providers – Measurement Solutions (Buildings and Construction)	11
1.12	Stage of Technological Innovation – Measurement Barriers (Buildings and Construction)	12
1.13	Stage of Technological Innovation – Measurement Solutions (Buildings and Construction)	13
1.14	Solution Providers – Stage of Technological Innovation (Buildings and Construction)	14
1.15	Stage of Technological Innovation – TI as Measurement Technology (Buildings and Construction)	15
1.16	TI as Measurement Technology – Measurement Barriers (Buildings and Construction)	16
1.17	Solution Providers – TI as Measurement Technology (Buildings and Construction)	17
1.18	TI as Measurement Technology – Measurement Solutions (Buildings and Construction)	18
1.19	Regulation as Driver/Barrier – Measurement Solutions (Buildings and Construction)	19
1.20	Solution Providers – Regulation as Driver/Barrier (Buildings and Construction)	20

Exhibit 1.1: MN Distribution of Measurement Barriers in Buildings and Construction

			Data, Data			Lack of		Not				Small		Syste		
			Collection			Fundamental			Production			market		ms-		
Acceptibility	Accessibility	Accuracy	& Retrieval	Destructive	Expense	Knowledge	Solutions	zed	Readiness	Reliability	Resolution	demand	Speed	level	Workforce	Total
3	0	7	13	0	1	4	3	9	1	5	1	0	1	1	0	49



1

Exhibit 1.2: MN Distribution of Measurement Solution Providers in Buildings and Construction

				Engineering													
	Commercial			Management/C		Independent								Standards			
	Calibration		Contractor	onsulting	Government	Testing/Certifica		Industry			National	Small		Development			
Calibration	Service	Component	R&D Labs-for-	Firms/A&E	Laboratories	tion	Industrial R&D	Consortium/	Instrument	Material	Measurement	Business/I	Software	Organizations	Testing		
Laboratories	Providers	Suppliers	Hire	Firms	and Agencies	Laboratories	Laboratories	Partnership	Suppliers	Suppliers	Institute	nventors	Developers	(SDO)	Laboratories	Universities	Total
0	0	2	0	0	11	3	5	7	3	1	15	0	1	8	1	8	65

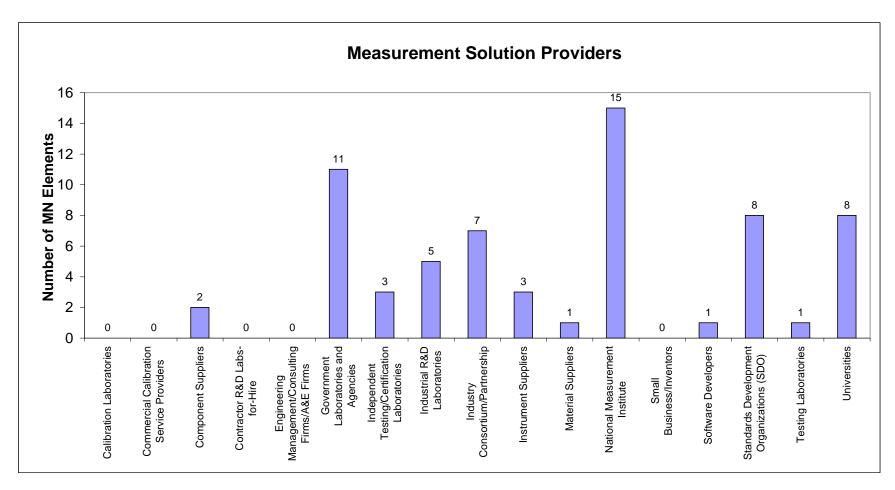


Exhibit 1.3: MN Distribution of Measurement Solutions in Buildings and Construction

				Infrastructu	ıre										Pro	ducts							S	ervices		L
						Research -												Standard/ce		Test methods or	Validated					
Coo	rdinat	Data	Development -	Fund-		Measure-				Computati	Measure-	Measure-						rtified	Test methods for	test data for	(hardened)		Expert	Intl		
ion/	Facilit	Collection/R	Measurement	amental		ment	Standar	User	Calibra	onal	ment	ment	Metrics/Benc	Raw	Reference	Softw	Stability	reference	production-scale	consumer	properties	Calibrati	consulta	Recogniti	Third Party	
atio	n e	etrieval	Technology	Knowledge	Protocols	Science	ds	Facility	tion	Methods	Instrument	Method	hmarks	Data	Data	are	Tests	material	measurements	products	data	on	tion	on	Verification	Total
	0	2	5	2	2	6	11	0	0	7	2	7	5	2	3	0	0	1	2	4	2	0	0	0	1	64

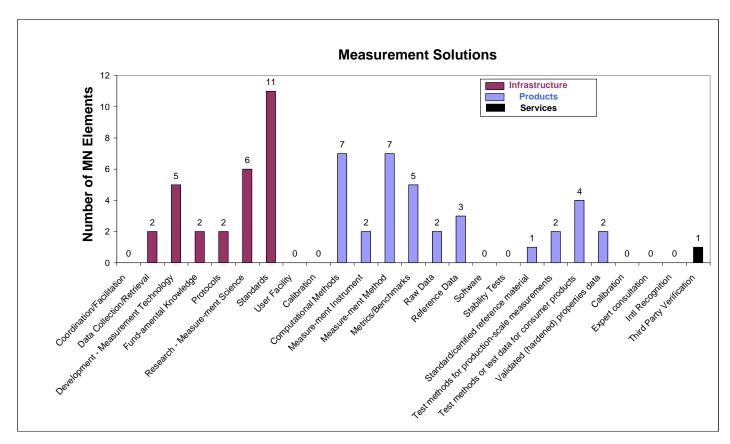


Exhibit 1.4: MN Distribution of Measurands in Buildings and Construction

		Clas	ssical						Functiona						Performance			Structu	ıral		
											Thermal-	Thermal-	Thermal-								
						Electronic/				Radio	Thermoch	Thermody	Thermoph	Computational	Software	System					1
Biolo	gical	Chemical	Physical	Physiological	Acoustical	Electrical	Magnetic	Optical	Photonic	frequency	emical	namic	ysical	Performance	Performance	Performance	Kinetic	Mechanical	Molecular	Spatial	Total
0)	1	3	2	0	3	0	0	1	0	0	1	4	1	0	3	0	2	0	2	23

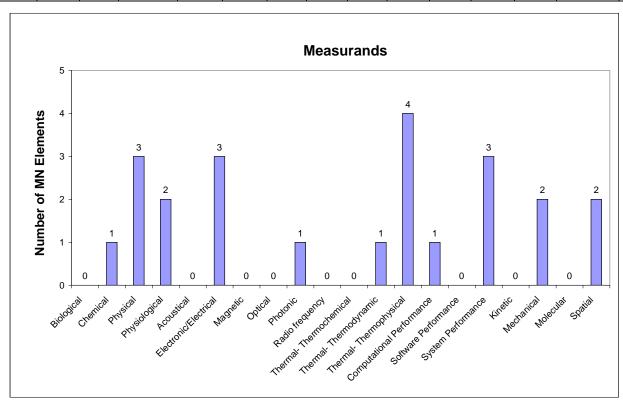


Exhibit 1.5: MN Distribution of Current Public/Private R&D Efforts in Buildings and Construction

1	•	Both Public and Private Efforts Exist	No Efforts Exist
1	2	4	16

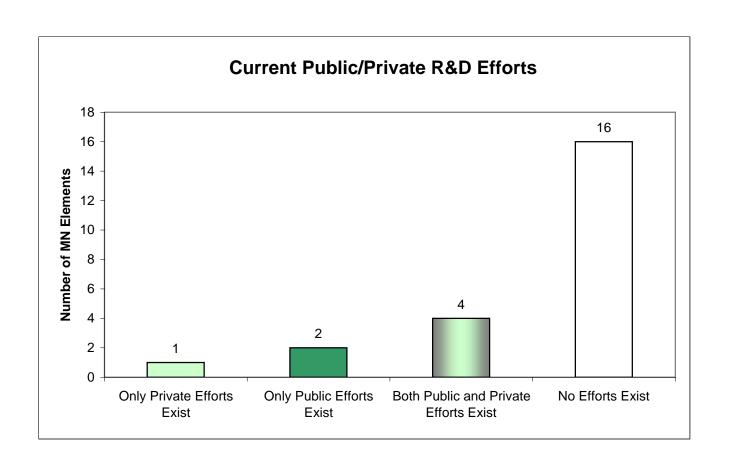


Exhibit 1.6: MN Distribution of TI as Measurement Technology in in Buildings and Construction

Technology Innovation	
is a Measurement	Technology Innovation is not a
Innovation	Measurement Innovation
7	16

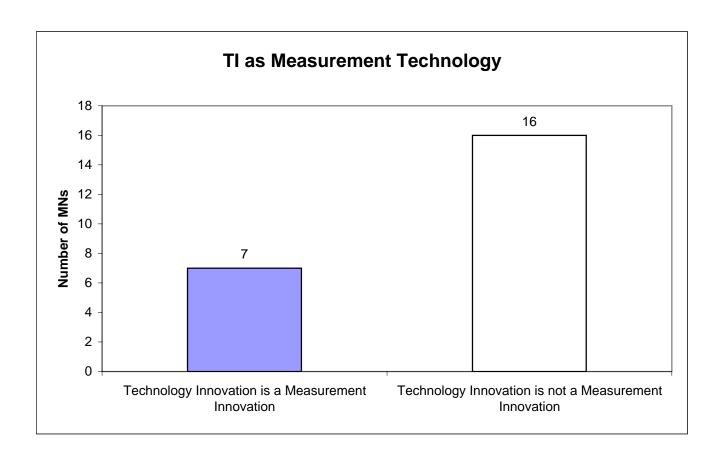


Exhibit 1.7: MN Distribution by Stage of Technological Innovation in Buildings and Construction

Applied Research	Production	Market	End-use	Total
13	1	8	1	23

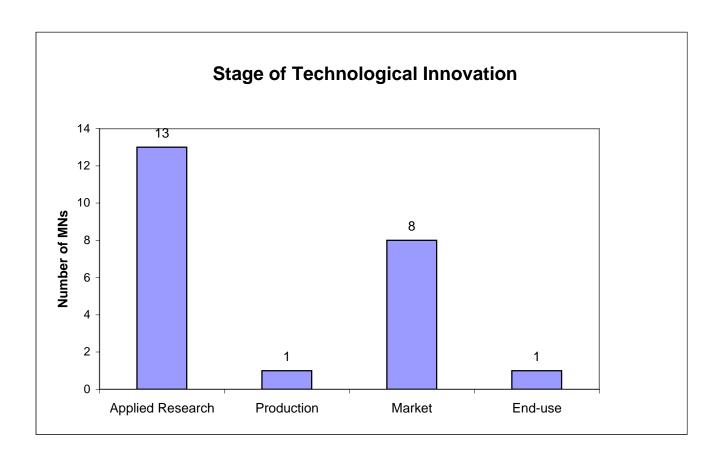


Exhibit 1.8: MN Distribution of Regulation as Driver/Barrier in Buildings and Construction

MN Driver	MN Barrier	No Impact	
1	2	20	C

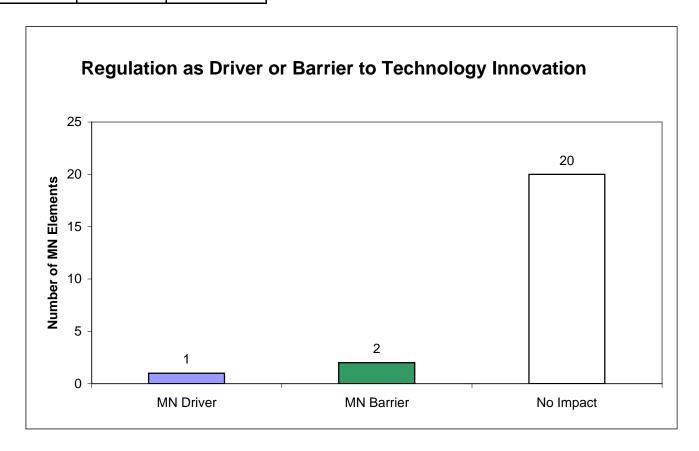


Exhibit 1.9: MN Correlation Matrix for Solution Providers and Measurement Barriers in Buildings and Construction

					Mea	sur	reme	nt S	olut	ion	Bar	riers	3			
Solution Providers	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Calibration laboratories							_						-,,	*		
Commercial calibration service providers																
Component suppliers	1		1	1				1	1							
Contractor R&D labs-for-hire																
Engineering management/consulting firms/A&E firms																
Government laboratories and agencies	1		3	7		1	1	1	4	1	2			1		
Independent testing/certification laboratories			2	2			1				2					
Industrial R&D laboratories			3	2					1	1	2					
Industry consortium/partnership	1		1	4			2	1	4		2				1	
Instrument suppliers	1		1	2					2			1				
Material suppliers				1			1									
National Measurement Institute	2		3	8		1	3	2	7		3	1		1	1	
Small business/inventors																
Software developers	1		1	1												
Standards development organizations (SDOs)			3	4				2	6		1	1				
Testing laboratories			1					1	1							
Universities	1		1	5			2	1	1	1	2					

Exhibit 1.10: MN Correlation Matrix for Measurement Barriers and Measurement Solutions in Buildings and Construction

									Me	eas	ure	mei	nt S	olu	tio	ns									
			Inf	rastru	ıctu	re								Р	rod	luc	ts					-	Serv	/ice	s
Measurement Solution Barriers	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Acceptability/Compatibility			1	1		2	2			1		1	1			-					1	Ť			
Accessibility											Ì														
Accuracy			2			3	2			3	1	4	2					1	1						
Data, Data Collection/and or																									
Retrieval		2		1	2	2	5			6	2	3	3	1	2				2		3 2	2			
Destructive																									
Expense		1								1					1										
Lack of Fundamental																									
Knowledge			1	2		3				1	1											1			
Multiple Solutions Exist			1				2				1	3		1											1
Not Standardized			2		2	1	8			1	1	3	1	1					1		4	1		Ш	1
Production Readiness			1											1	1										
Reliability		1	2			2	2			3		1	2								1				
Resolution							1						1								1			\square	
Small Market Demand																								Ш	
Speed		1								1					1									Ш	
System-Level Problem			1			1																			
Workforce																									

Exhibit 1.11: MN Correlation Matrix for Measurement Providers and Measurement Solutions in Buildings and Construction

										Mea	sur	eme	nt S	olu	tions	5									
			Infra	astru	ıctu	re								Pro	oduc	ts						5	ervi	ces	
	Coordination/ facilitation	ta Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Measurement Solution Providers	ပိ	Data	Ď	Ŀ	Pro	Re	Sta	NS	Ca	ပိ	Me	Me	Me	Ra	Re	So	Sta	Sta	Te	ĕ	Va	င်ခ	Ä	<u>r</u>	3rc
Calibration laboratories																									
Commercial calibration service providers																									
Component suppliers							1			1		2	1												1
Contractor R&D labs-for-hire																									
Engineering management/consulting firms/A&E firms																									
Government laboratories and agencies		2	2		1	3	4			2	1	3	1	2	3			1	1	2	1				
Independent testing/certification laboratories		1				2	1			2	1	1	1												
Industrial R&D laboratories		•	2			2	2			1	•	1	1	1	1				1	1	1				-
Industry consortium/partnership			3	1	1	2	5			2		2	1	-					1	1	1				$\overline{}$
Instrument suppliers					1		2			1		1	2						1	1	-				\neg
Material suppliers				1			1			•		-								-	1				\neg
National Measurement Institute		1	3	1	1	4	7			5	2	4	3	1	2			1		4	1				1
Small business/inventors		•		-		-	•			J		-		-						-	-				
Software developers										1		1	1												\dashv
Standards development organizations (SDOs)										•															
Claritation de de la constitución de de la constitución de de la constitución de la const			1		2	1	6			1		3	1					1	2	3					1
Testing laboratories			1				1					1													
Universities		1	2	2		1	2			3	1	2	3	2	2						1				

Exhibit 1.12: MN Correlation Matrix for Stage of Technological Innovation and Measurement Barriers in Buildings and Construction

					Me	easu	reme	nt S	olut	ion l	Barrie	ers				
Stage of Technological Innovation	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Applied Research	1		6				2	2			3	1			1	
Production				1							1					
Market	2		1	6			2	1	5		1					
End-use				1		1								1		

Exhibit 1.13: MN Correlation Matrix for Stage of Technological Innovation and Measurement Solutions in Buildings and Construction

									М	eas	ure	mei	nt S	olu	tio	ns										
			Inf	rastrı	ıctı	ıre								Р	rod	luct	ts						S	erv	ice	s
Stage of Technological Innovation	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production	Test Methods - Consumer	roducts	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Applied Research			4	1	1	,	3 6	6		3	1	5	3	1	2			1			2	1				1
Production		1								1			1													
Market			1	1	1		3 5	5		2	1	2	1	1						2	2	1				
End-use		1								1					1											

Exhibit 1.14: MN Correlation Matrix for Solution Providers and Stage of Technological Innovation in Buildings and Construction

	Stage (nologi	cal
Measurement Solution Providers	Applied Research	Production	Market	End-use
Calibration laboratories			_	_
Commercial calibration service providers				
Component suppliers	2			
Contractor R&D labs-for-hire				
Engineering management/consulting firms/A&E firms				
Government laboratories and agencies	5	1	4	1
Independent testing/certification laboratories	2	1		
Industrial R&D laboratories	3		2	
Industry consortium/partnership	3		4	
Instrument suppliers	2		1	
Material suppliers	1			
National Measurement Institute	8		6	1
Small business/inventors				
Software developers	1			
Standards development organizations (SDOs)	5		3	
Testing laboratories	1			
Universities	4	1	3	

Exhibit 1.15: MN Correlation Matrix for Stage of Technological Innovation and TI as Measurement Technology in Buildings and Construction

Stage of Technological Innovation	TI as Measurement Technology
Applied Research	4
Production	
Market	2
End-use	1

Exhibit 1.16: MN Correlation Matrix for TI as Measurement Technology and Measurement Barriers in Buildings and Construction

			1		Me	asu	reme	nt S	olut	ion l	Barrie	ers				
Innovation Equivalency	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Technology Innovation = Measurement Innovation			1	5		1	1	1	4		1	1		1	1	

Exhibit 1.17: MN Correlation Matrix for Solution Providers and TI as Measurement Technology in Buildings and Construction

Measurement Solution Providers	Technology Innovation = Measurement Innovation
Calibration laboratories	
Commercial calibration service providers	
Component suppliers	
Contractor R&D labs-for-hire	
Engineering management/consulting firms/A&E firms	
Government laboratories and agencies	3
Independent testing/certification laboratories	1
Industrial R&D laboratories	
Industry consortium/partnership	2
Instrument suppliers	2
Material suppliers	
National Measurement Institute	6
Small business/inventors	
Software developers	
Standards development organizations (SDOs)	3
Testing laboratories	
Universities	1

Exhibit 1.18: MN Correlation Matrix for TI as Measurement Technology and Measurement Solutions in Buildings and Construction

										Me	eası	ıren	nent	So	lutio	ns									
			Infr	astr	uctu	ıre								Р	rodu	ıcts						;	Serv	ices	i
Innovation Equivalency	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Technology Innovation = Measurement		4	4		2	2	3			2	2	1	4	1	4				4	2					
Innovation	$oxed{oxed}$	- 1	- 1		2	Z	3			Z		- 1	- 1		- 1							ļ			

Exhibit 1.19: MN Correlation Matrix for Regulation as Driver/Barrier and Measurement Solutions in Buildings and Construction

										M	eası	ıren	nent	Sol	utio	ns									
			Infr	astr	uct	ure								Pro	oduc	cts						9	Serv	ices	
Regulatory Issues	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Regulation is a Driver						1				1	1														
Regulation is a Barrier		2								2			1		1										

Exhibit 1.20: MN Correlation Matrix for Solution Providers and Regulation as Driver/Barrier in Buildings and Construction

Measurement Solution Providers	Regulation is a Driver	Regulation is a Barrier
Calibration laboratories	_	_
Commercial calibration service providers		
Component suppliers		
Contractor R&D labs-for-hire		
Engineering management/consulting firms/A&E firms		
Government laboratories and agencies		2
Independent testing/certification laboratories	1	1
Industrial R&D laboratories		
Industry consortium/partnership		
Instrument suppliers		
Material suppliers		
National Measurement Institute	1	1
Small business/inventors		
Software developers		
Standards development organizations (SDOs)		
Testing laboratories		
Universities		1

U.S. Measurement System

Measurement Need (MN) Data Book

Chapter 2. Chemicals, Industrial Biotechnology, and Continuous Manufacturing

Prepared by
Energetics Incorporated
for the
National Institute of Standards and Technology

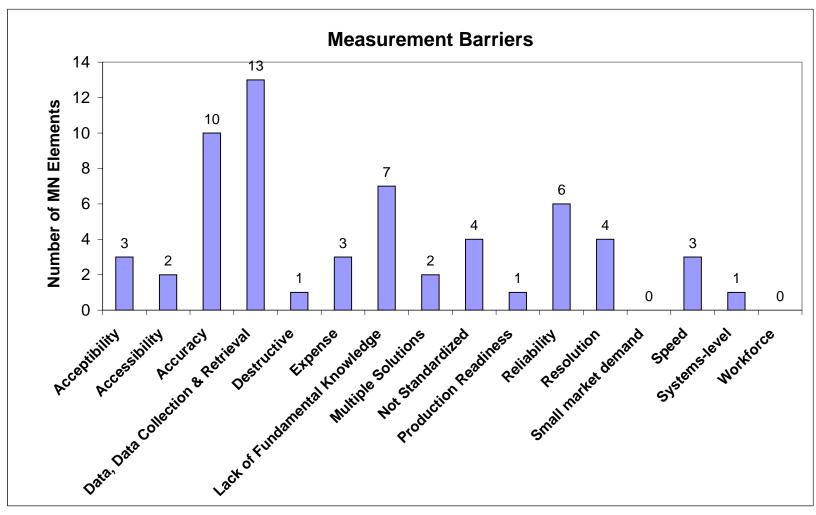
April 2006

Reference List of MN Distribution Charts and MN Correlation Matrices

Distributio	n Charts	Page
Exhibit Num	nber	
2.1	Measurement Barriers (Chemicals, Industrial Biotech, and Continuous Mfg)	1
2.2	Solution Providers (Chemicals, Industrial Biotech, and Continuous Mfg)	2
2.3	Measurement Solutions (Chemicals, Industrial Biotech, and Continuous Mfg)	3
2.4	Measurands (Chemicals Industrial Biotech, and Continuous Mtd)	4
2.5	Current Public/Private R&D Efforts (Chemicals, Industrial Biotech, and Continuous Mfg)	5
2.6	TI as Measurement Technology (Chemicals, Industrial Biotech, and Continuous Mfg)	6
2.7	Stage of Technological Innovation (Chemicals, Industrial Biotech, and Continuous Mfg)	7
2.8	Regulation as Driver/Barrier (Chemicals, Industrial Biotech, and Continuous Mfg)	8
Correlation		
Exhibit Num		_
2.9	Solution Providers – Measurement Barriers (Chemicals, Industrial Biotech, and Continuous Mfg)	9
2.10	Measurement Barriers – Measurement Solutions (Chemicals, Industrial Biotech, and Continuous Mfg)	10
2.11	Solution Providers – Measurement Solutions (Chemicals, Industrial Biotech, and Continuous Mfg)	11
2.12	Stage of Technological Innovation – Measurement Barriers (Chemicals, Industrial Biotech, and Continuous Mfg)	12
2.13	Stage of Technological Innovation – Measurement Solutions (Chemicals, Industrial Biotech, and Continuous Mfg)	
2.14	Solution Providers – Stage of Technological Innovation (Chemicals, Industrial Biotech, and Continuous Mfg)	14
2.15	Stage of Technological Innovation – TI as Measurement Technology (Chemicals, Industrial Biotech, and Continuous Mfg)	15
2.16	TI as Measurement Technology – Measurement Barriers (Chemicals, Industrial Biotech, and Continuous Mfg)	16
2.17	Solution Providers – TI as Measurement Technology (Chemicals, Industrial Biotech, and Continuous Mfg)	
2.18	TI as Measurement Technology – Measurement Solutions (Chemicals, Industrial Biotech, and Continuous Mfg)	18
2.19	Regulation as Driver/Barrier – Measurement Solutions (Chemicals, Industrial Biotech, and Continuous Mfg)	19
2.20	Solution Providers – Regulation as Driver/Barrier (Chemicals, Industrial Biotech, and Continuous Mfg)	20

Exhibit 2.1: MN Distribution of Measurement Barriers in Chemicals, Industrial Biotech, and Continuous Mfg

			Data, Data			Lack of		Not				Small		Syste		
			Collection			Fundamental	Multiple	Standardi	Production	Reliabil	Resolut	market		ms-		1
Acceptibility	Accessibility	Accuracy	& Retrieval	Destructive	Expense	Knowledge	Solutions	zed	Readiness	ity	ion	demand	Speed	level	Workforce	Total
3	2	10	13	1	3	7	2	4	1	6	4	0	3	1	0	60



1

Exhibit 2.2: MN Distribution of Measurement Solution Providers in Chemicals, Industrial Biotech, and Continuous Mfg

				Engineering													
	Commercial			Management/C		Independent								Standards			
	Calibration		Contractor	onsulting	Government	Testing/Certifica		Industry			National	Small		Development			
Calibration	Service	Component	R&D Labs-for-	Firms/A&E	Laboratories	tion	Industrial R&D	Consortium/	Instrument	Material	Measurement	Business/I	Software	Organizations	Testing		
Laboratories	Providers	Suppliers	Hire	Firms	and Agencies	Laboratories	Laboratories	Partnership	Suppliers	Suppliers	Institute	nventors	Developers	(SDO)	Laboratories	Universities	Total
0	0	1	0	1	12	1	2	6	7	1	16	0	3	3	0	8	61

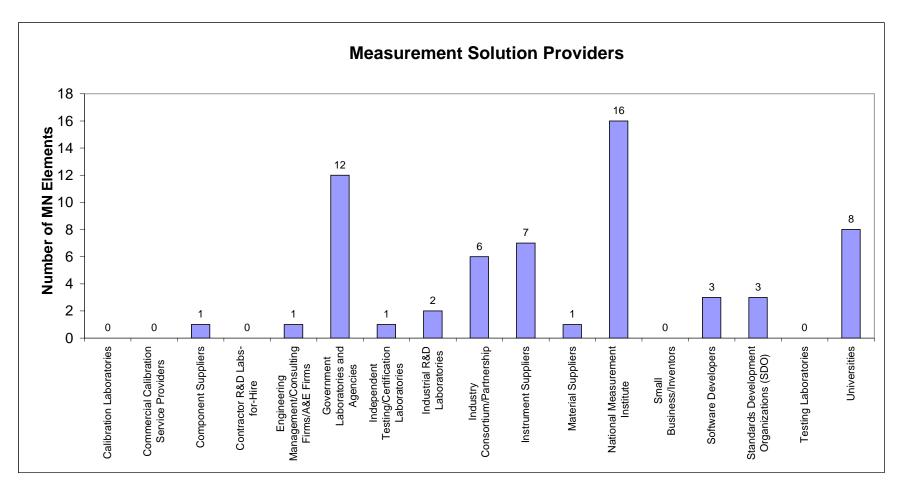


Exhibit 2.3: MN Distribution of Measurement Solutions in Chemicals, Industrial Biotech, and Continuous Mfg

Infrastructure									Products											<u> </u>					
					Research -				l								Standard/ce		Test methods or	Validated					
Coordi	nat Data	Development -	Fund-		Measure-				Computati	Measure-	Measure-						rtified	Test methods for	test data for	(hardened)		Expert	Intl		
ion/Fac	ilit Collection/R	Measurement	amental		ment	Standar	User	Calibra	onal	ment	ment	Metrics/Benc	Raw	Reference	Softw	Stability	reference	production-scale	consumer	properties	Calibrati	consulta	Recogniti	Third Party	
ation	etrieval	Technology	Knowledge	Protocols	Science	ds	Facility	tion	Methods	Instrument	Method	hmarks	Data	Data	are	Tests	material	measurements	products	data	on	tion	on	Verification	Total
2	3	7	4	1	4	8	3	4	3	5	7	0	0	3	1	0	2	1	2	0	0	0	0	2	62

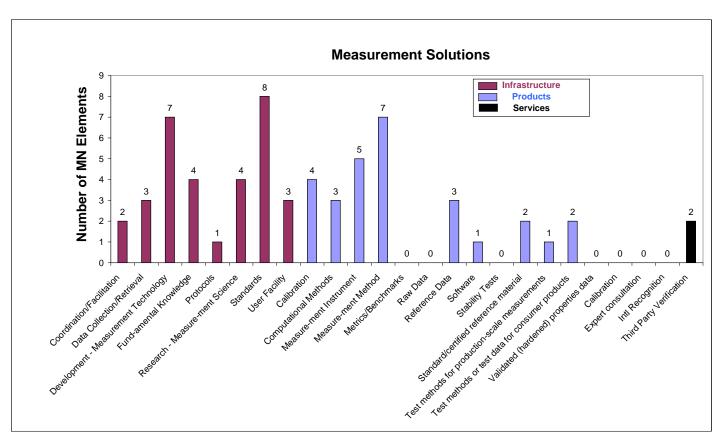


Exhibit 2.4: MN Distribution of Measurands in Chemicals, Industrial Biotech, and Continuous Mfg

	Classical Functional								Structural											
										Thermal-	Thermal-	Thermal-								
					Electronic/				Radio	Thermoch	Thermody	Thermoph	Computational	Software	System					
Biological	Chemical	Physical	Physiological	Acoustical	Electrical	Magnetic	Optical	Photonic	frequency	emical	namic	ysical	Performance	Performance	Performance	Kinetic	Mechanical	Molecular	Spatial	Total
4	5	2	0	0	1	1	2	0	0	0	1	2	1	1	0	0	2	0	0	22

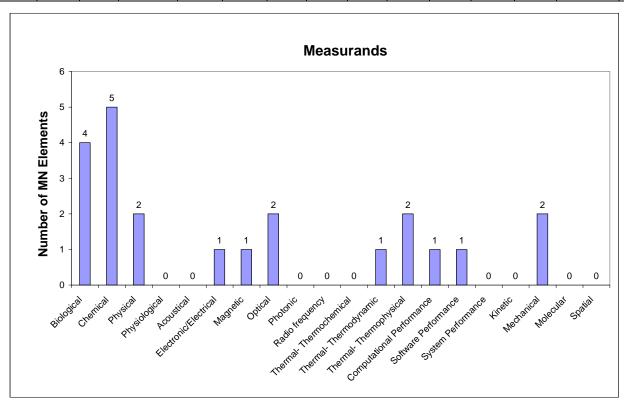


Exhibit 2.5: MN Distribution of Current Public/Private R&D Efforts in Chemicals, Industrial Biotech, and Continuous Mfg

Only Drivets	Onder Broklin	Doth Bullio and	
1	•	Both Public and Private Efforts Exist	No Efforts Exist
1	3	5	13

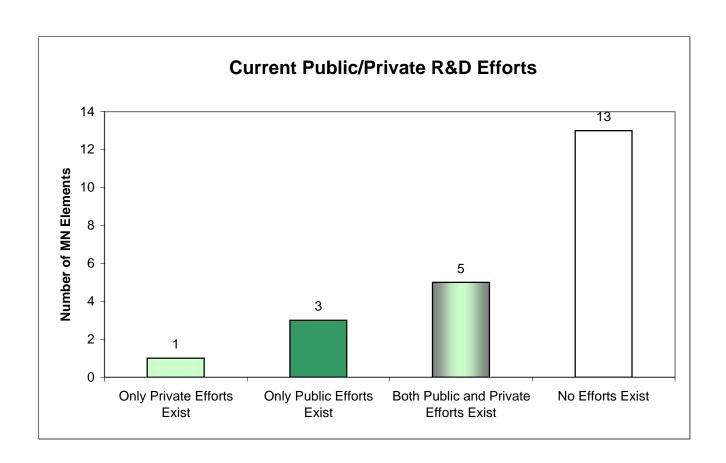


Exhibit 2.6: MN Distribution of TI as Measurement Technology in Chemicals, Industrial Biotech, and Continuous Mfg

Technology Innovation	
is a Measurement	Technology Innovation is not a
Innovation	Measurement Innovation
11	11

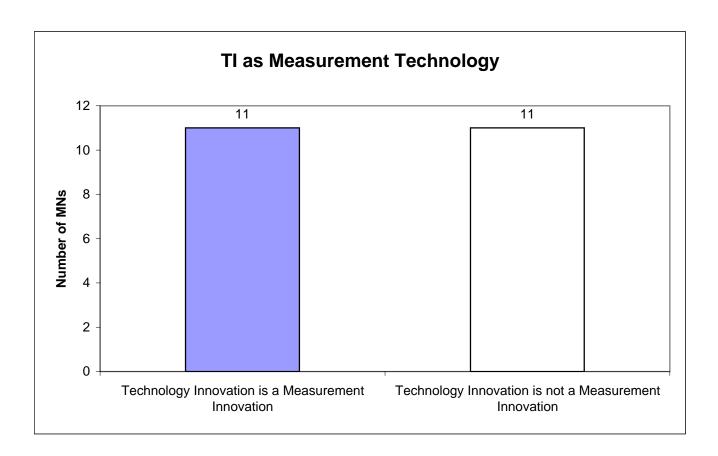


Exhibit 2.7: MN Distribution by Stage of Technological Innovation in Chemicals, Industrial Biotech, and Continuous Mfg

Applied Research	Production	Market	End-use	Total
15	5	2	0	22

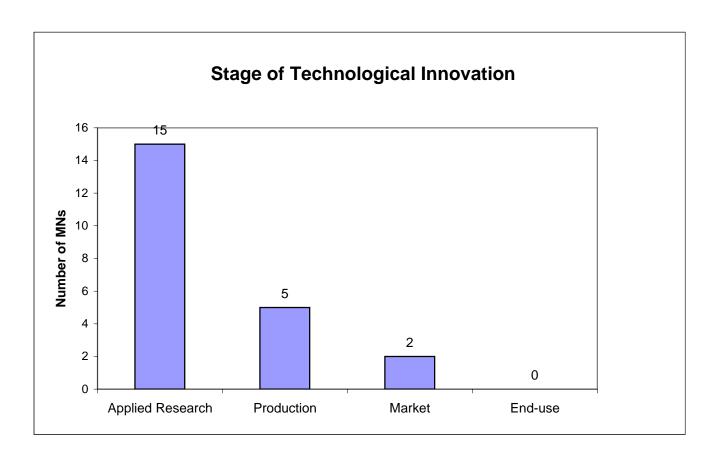


Exhibit 2.8: MN Distribution by Regulation as Driver/Barrier in Chemicals, Industrial Biotech, and Continuous Mfg

MN Driver	MN Barrier	No Impact	
1	0		21

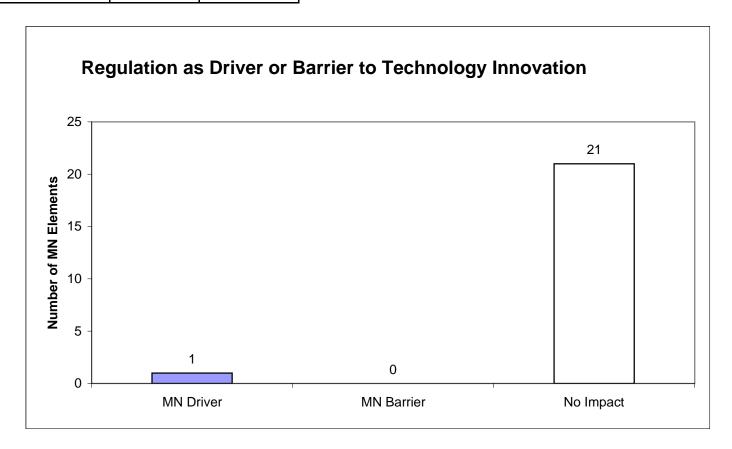


Exhibit 2.9: MN Correlation Matrix for Solution Providers and Measurement Barriers in Chemicals, Industrial Biotech, and Continuous Mfg

					Me	asu	reme	nt S	olut	ion I	Barrie	ers				
Solution Providers	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Calibration laboratories			·													
Commercial calibration service providers																
Component suppliers			1					1			1					
Contractor R&D labs-for-hire																
Engineering management/consulting firms/A&E firms				1							1				1	
Government laboratories and agencies	1	1	6	6	1	2	3	1	1	1	2	3		3		
Independent testing/certification laboratories	1			1					1							
Industrial R&D laboratories			2					1			1					
Industry consortium/partnership	1	1	2	3		2	2		1		1			2		
Instrument suppliers	2		4	4		1	3		3	1		3				
Material suppliers			1				1		1							
National Measurement Institute	3	2	6	10	1	2	6	2	4		3	3		2	1	
Small business/inventors																
Software developers		1	1	3			1				2					
Standards development organizations (SDOs)			1	2	1		1				2			1		
Testing laboratories																
Universities		1	3	5		1	3	1	1	1	2	2		1		

Exhibit 2.10: MN Correlation Matrix for Measurement Barriers and Measurement Solutions in Chemicals, Industrial Biotech, and Continuous Mfg

									M	eas	ure	me	nt S	Solu	ıtio	ns									
			Inf	rastru	ıctι	ıre								Р	roc	duc	ts					S	erv	ice	s
Measurement Solution Barriers	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Acceptability/Compatibility)				_	ш 0,	1	1	1)		1	_	_	1	0,	0,	0,	1	2				_	1
Accessibility		1					1			1	1	1			1										
Accuracy	1	1	5		1	3	3	3	3	1	3							1	1						
Data, Data Collection/and or																									
Retrieval	2	3	3	3	1		4	2	2	3	3	4			3	1		1		2					2
Destructive							1					1						1							
Expense			1			1	2	1	1		1	1							1						
Lack of Fundamental																									
Knowledge		1	2			1	3		1	2	1	4			1			1							
Multiple Solutions Exist			2			1			1		1	1													
Not Standardized			2	1			2		1			2			1					2					1
Production Readiness			1																						
Reliability	2	2	1		1	1	2	1	1	1	2				1	1		1							1
Resolution			3	1				1	1		2	2													
Small Market Demand																									
Speed			1			1	3				1	2						1							
System-Level Problem	1	1														1									
Workforce																									

Exhibit 2.11: MN Correlation Matrix for Measurement Providers and Measurement Solutions in Chemicals, Industrial Biotech, and Continuous Mfg

										Mea	sur	eme	ent S	olut	tions	5									
			Infra	astru	ıctuı	e								Pro	oduc	ts						5	ervi	ces	
Management Columbia Branislana	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Measurement Solution Providers	ŭ	۵	۵	Ē	Ē	ĕ	ร	Š	Ü	ŭ	Σ	Σ	Σ	æ	Š	ŭ	Ş	જ	ř	Ĕ	×	Ü	û	므	<u>~</u>
Calibration laboratories																									
Commercial calibration service providers			4			1					1														
Component suppliers			1			1					1														
Contractor R&D labs-for-hire																									
Engineering management/consulting firms/A&E firms	1	1														1									
Government laboratories and agencies	1	1	4	2	1	3	5	1	1	2	3	4						2		1					1
Independent testing/certification laboratories												1			1					1					
Industrial R&D laboratories			1			2					1														
Industry consortium/partnership			1	2	1	2	3			1	2				1			1		1					
Instrument suppliers			4	2			2	2	2		2	2							1	1					1
Material suppliers			1				1		1																
National Measurement Institute	1	2	5	3		2	6	3	4	2	4	6			2	1		1	1	2					1
Small business/inventors																									
Software developers	1	2					1			2					2										1
Standards development organizations (SDOs)					1		2				1	1			1			2							1
Testing laboratories						İ																			
Universities	1	2	4	2		2	2		1	2		3			2										1

Exhibit 2.12: MN Correlation Matrix for Stage of Technological Innovation and Measurement Barriers in Chemicals, Industrial Biotech, and Continuous Mfg

					Me	easu	reme	nt S	olu	ion l	Barrie	ers				
Stage of Technological	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	peeds	System-Level Problem	Workforce
Applied Research		2	6			2	6	2	1		4	3		3		
Production	2		3	2		1	1		2	1	1	1			1	
Market	1		1	2					1		1					
End-use																

Exhibit 2.13: MN Correlation Matrix for Stage of Technological Innovation and Measurement Solutions in Chemicals, Industrial Biotech, and Continuous Mfg

									M	eas	ure	me	nt S	Solu	ıtio	ns									
			Infr	astru	ctu	re								P	roc	luc	ts					9,	Serv	/ice	s
Stage of Technological Innovation	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Applied Research	1	2	5	4		4	6	2	2	3	4	6			2			1							1
Production	1	1	2				1	1	2			1			1	1			1	1					
Market					1		1				1							1		1					1
End-use																									

Exhibit 2.14: MN Correlation Matrix for Solution Providers and Stage of Technological Innovation in Chemicals, Industrial Biotech, and Continuous Mfg

	Stage (nologi	cal
Measurement Solution Providers	Applied Research	Production	Market	End-use
Calibration laboratories		_	_	_
Commercial calibration service providers				
Component suppliers	1			
Contractor R&D labs-for-hire				
Engineering management/consulting firms/A&E firms		1		
Government laboratories and agencies	9	1	2	
Independent testing/certification laboratories		1		
Industrial R&D laboratories	2			
Industry consortium/partnership	4	1	1	
Instrument suppliers	3	3	1	
Material suppliers		1		
National Measurement Institute	11	4	1	
Small business/inventors				
Software developers	3			
Standards development organizations (SDOs)	2		1	
Testing laboratories				
Universities	7	1		

Exhibit 2.15: MN Correlation Matrix for Stage of Technological Innovation and TI as Measurement Technology in Chemicals, Industrial Biotech, and Continuous Mfg

Stage of Technological Innovation	TI as Measurement Technology
Applied Research	9
Production	2
Market	
End-use	

Exhibit 2.16: MN Correlation Matrix for TI as Measurement Technology and Measurement Barriers in Chemicals, Industrial Biotech, and Continuous Mfg

				1	Me	asu	reme	nt S	olut	ion l	Barrie	ers				
Innovation Equivalency	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Technology Innovation = Measurement Innovation		1	5	7			5	2	2		4	2			1	

Exhibit 2.17: MN Correlation Matrix for Solution Providers and TI as Measurement Technology in Chemicals, Industrial Biotech, and Continuous Mfg

Measurement Solution Providers	Technology Innovation = Measurement Innovation
Calibration laboratories	
Commercial calibration service providers	
Component suppliers	1
Contractor R&D labs-for-hire	
Engineering management/consulting firms/A&E firms	1
Government laboratories and agencies	4
Independent testing/certification laboratories	
Industrial R&D laboratories	2
Industry consortium/partnership	1
Instrument suppliers	3
Material suppliers	1
National Measurement Institute	9
Small business/inventors	
Software developers	2
Standards development organizations (SDOs)	
Testing laboratories	
Universities	5

Exhibit 2.18: MN Correlation Matrix for TI as Measurement Technology and Measurement Solutions in Chemicals, Industrial Biotech, and Continuous Mfg

										M	eası	ıren	nent	So	lutio	ns									
			Infr	astr	uctu	ıre								Р	rodu	ıcts							Serv	ices	5
Innovation Equivalency	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	8	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Technology Innovation = Measurement Innovation	2	3	4	3		3	2	1	3	2	2	4			1	1									
IIIIOVation		U		U		U			U												1				

Exhibit 2.19: MN Correlation Matrix for Regulation as Driver/Barrier and Measurement Solutions in Chemicals, Industrial Biotech, and Continuous Mfg

										N	leas	urei	nen	t So	lutio	ons									
			Infr	astı	ructi	ure								Pro	odu	cts							Ser	vice	S
Regulatory Issues	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Regulation is a Driver	1	1														1									
Regulation is a Barrier																									

Exhibit 2.20: MN Correlation Matrix for Solution Providers and Regulation as Driver/Barrier in Chemicals, Industrial Biotech, and Continuous Mfg

Measurement Solution Providers	Regulation is a Driver	Regulation is a Barrier
Calibration laboratories		
Commercial calibration service providers		
Component suppliers		
Contractor R&D labs-for-hire		
Engineering management/consulting firms/A&E firms	1	
Government laboratories and agencies		
Independent testing/certification laboratories		
Industrial R&D laboratories		
Industry consortium/partnership		
Instrument suppliers		
Material suppliers		
National Measurement Institute	1	
Small business/inventors		
Software developers		
Standards development organizations (SDOs)		
Testing laboratories		
Universities		

U.S. Measurement System

Measurement Need (MN) Data Book

Chapter 3. Defense and Homeland Security

(includes First Responders)

Prepared by
Energetics Incorporated
for the
National Institute of Standards and Technology

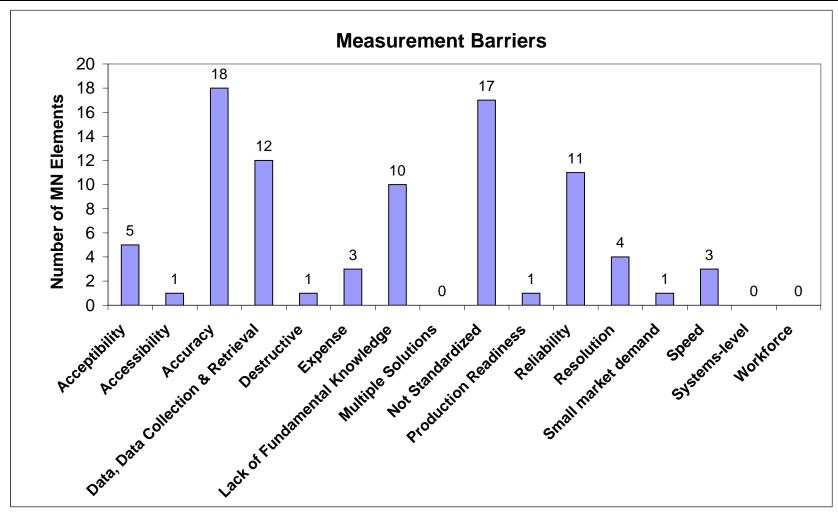
April 2006

Reference List of MN Distribution Charts and MN Correlation Matrices

Distribution	n Charts	Page
Exhibit Num	nber	
3.1	Measurement Barriers (Defense and Homeland Security)	1
3.2	Solution Providers (Defense and Homeland Security)	2
3.3	Measurement Solutions (Defense and Homeland Security)	3
3.4	Measurands (Defense and Homeland Security)	4
3.5	Current Public/Private R&D Efforts (Defense and Homeland Security)	5
3.6	TI as Measurement Technology (Defense and Homeland Security)	6
3.7	Stage of Technological Innovation (Defense and Homeland Security)	7
3.8	Regulation as Driver/Barrier (Defense and Homeland Security)	8
Correlation	n Matrices	
Exhibit Num	nber	
3.9	Solution Providers – Measurement Barriers (Defense and Homeland Security)	9
3.10	Measurement Barriers – Measurement Solutions (Defense and Homeland Security)	10
3.11	Solution Providers – Measurement Solutions (Defense and Homeland Security)	11
3.12	Stage of Technological Innovation – Measurement Barriers (Defense and Homeland Security)	12
3.13	Stage of Technological Innovation – Measurement Solutions (Defense and Homeland Security)	13
3.14	Colution Dravidore Ctors of Tashaslasical Innovation (Defense and Hamaland Convity)	14
3.15	Stage of Technological Innovation – TI as Measurement Technology (Defense and Homeland Security)	15
3.16	TI as Measurement Technology – Measurement Barriers (Defense and Homeland Security)	16
3.17	Solution Providers – TI as Measurement Technology (Defense and Homeland Security)	17
3.18	TI as Measurement Technology – Measurement Solutions (Defense and Homeland Security)	18
3.19	Regulation as Driver/Barrier – Measurement Solutions (Defense and Homeland Security)	19
3.20	Solution Providers – Regulation as Driver/Barrier (Defense and Homeland Security)	20

Exhibit 3.1: MN Distribution of Measurement Barriers in Defense and Homeland Security

																I	
			Data, Data			Lack of		Not				Small		Syste			
			Collection			Fundamental	Multiple	Standardi	Production	Reliabil	Resolut	market		ms-	Workforc		
Acceptibility	Accessibility	Accuracy	& Retrieval	Destructive	Expense	Knowledge	Solutions	zed	Readiness	ity	ion	demand	Speed	level	е	Total	
5	1	18	12	1	3	10	0	17	1	11	4	1	3	0	0	87	1



1

Exhibit 3.2: MN Distribution of Measurement Solution Providers in Defense and Homeland Security

				Engineering													
	Commercial			Management/C		Independent								Standards			
	Calibration		Contractor	onsulting	Government	Testing/Certifica		Industry			National	Small		Development			
Calibration	Service	Component	R&D Labs-for-	Firms/A&E	Laboratories	tion	Industrial R&D	Consortium/	Instrument	Material	Measurement	Business/I	Software	Organizations	Testing		
Laboratories	Providers	Suppliers	Hire	Firms	and Agencies	Laboratories	Laboratories	Partnership	Suppliers	Suppliers	Institute	nventors	Developers	(SDO)	Laboratories	Universities	Total
0	1	1	2	1	23	0	6	3	12	1	30	0	2	5	0	8	95

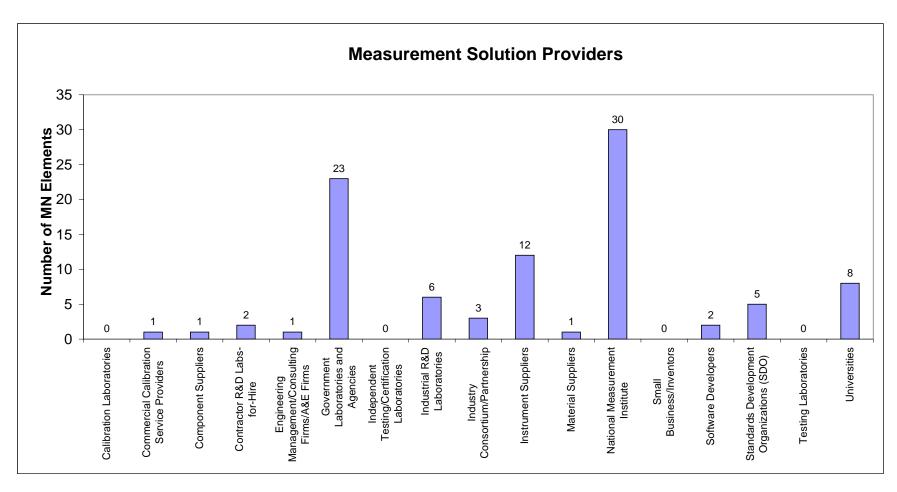


Exhibit 3.3: MN Distribution of Measurement Solutions in Defense and Homeland Security

			Infrastruct	ure				Products											S	ervices		1			
					Research -												Standard/ce		Test methods or	Validated					
Coordina	Data	Devolpment -	Fund-		Measure-				Computati	Measure-	Measure-						rtified	Test methods for	test data for	(hardened)		Expert	Intl		
ion/Facili	t Collection/R	Measurement	amental		ment	Standar	User	Calibra	onal	ment	ment	Metrics/Benc	Raw	Reference	Softw	Stability	reference	production-scale	consumer	properties	Calibrati	consulta	Recogniti	Third Party	
ation	etrieval	Technology	Knowledge	Protocols	Science	ds	Facility	tion	Methods	Instrument	Method	hmarks	Data	Data	are	Tests	material	measurements	products	data	on	tion	on	Verification	Total
0	2	7	4	4	3	8	2	6	4	8	11	7	3	4	0	1	4	3	6	1	0	1	0	2	91

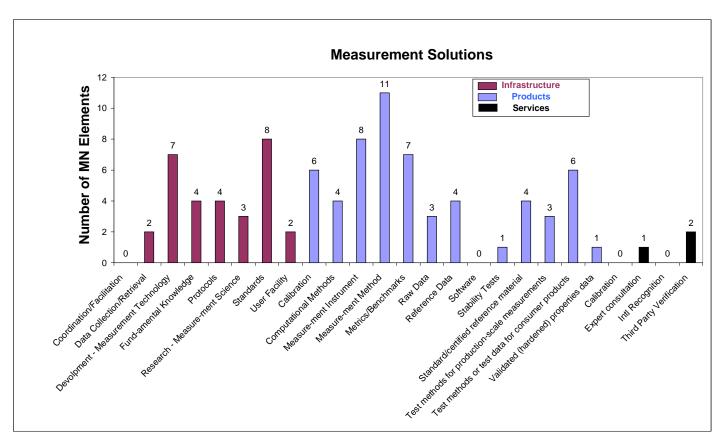


Exhibit 3.4: MN Distribution of Measurands in Defense and Homeland Security

		Clas	ssical	Functional										Performance			Structu	ural			
											Thermal-	Thermal-	Thermal-								
						Electronic/				Radio	Thermoch	Thermody	Thermoph	Computational	Software	System					
Biolo	ogical	Chemical	Physical	Physiological	Acoustical	Electrical	Magnetic	Optical	Photonic	frequency	emical	namic	ysical	Performance	Performance	Performance	Kinetic	Mechanical	Molecular	Spatial	Total
1	1	2	6	0	2	1	3	3	2	2	0	0	1	0	0	8	1	1	0	1	34

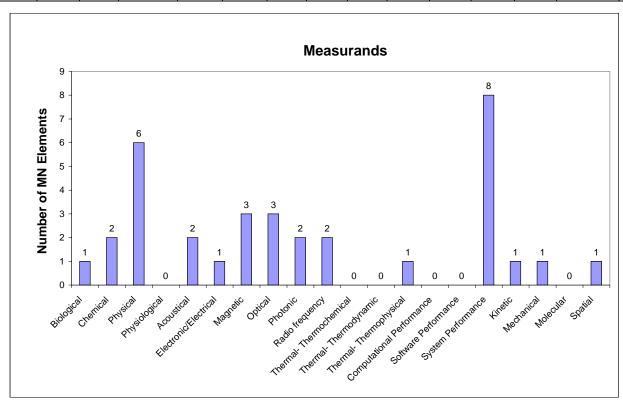


Exhibit 3.5: MN Distribution of Current Public/Private R&D Efforts in Defense and Homeland Security

1	,	Both Public and Private Efforts Exist	No Efforts Exist
3	7	5	19

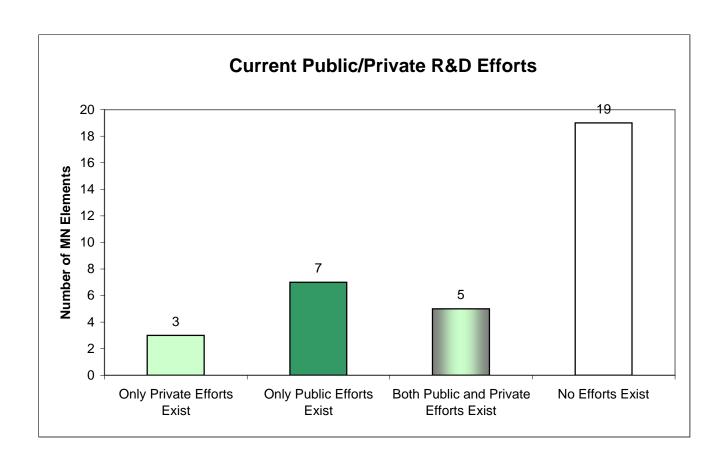


Exhibit 3.6: MN Distribution of TI as Measurement Technology in Defense and Homeland Security

	Technology Innovation is not a Measurement Innovation
19	15

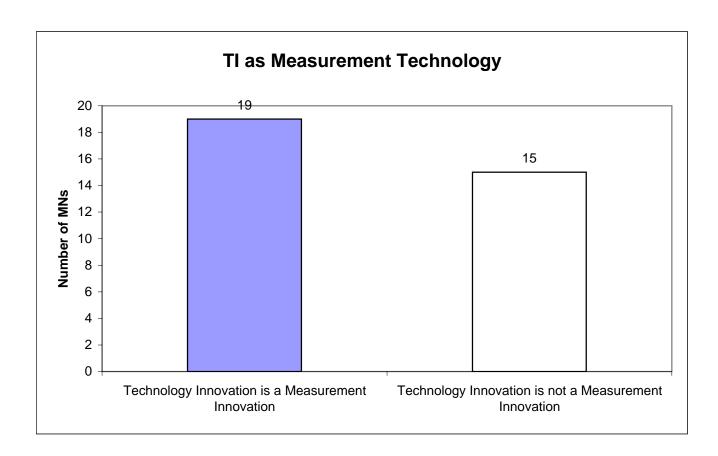


Exhibit 3.7: MN Distribution by Stage of Technological Innovation in Defense and Homeland Security

Applied Research	Production	Market	End-use	Total
27	2	3	2	34

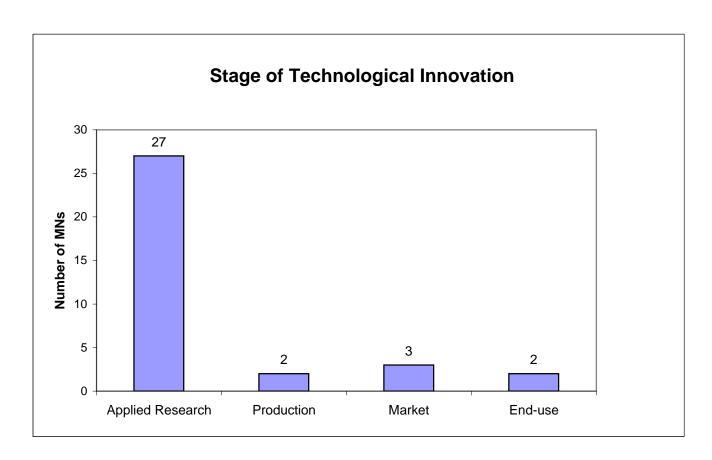


Exhibit 3.8: MN Distribution of Regulation as Driver/Barrier in Defense and Homeland Security

MN Driver	MN Barrier	No Impact	
3	1		30

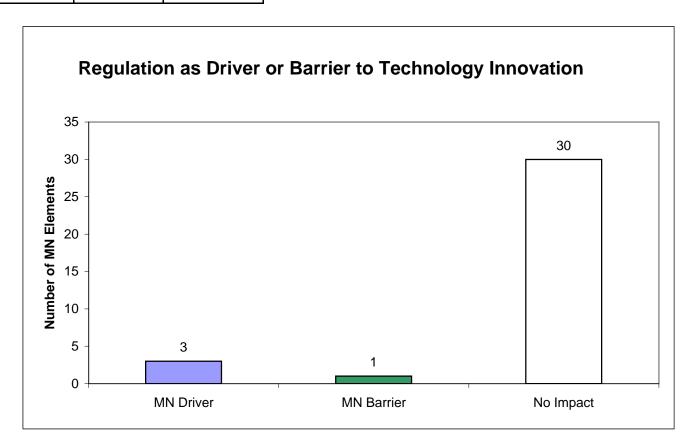


Exhibit 3.9: MN Correlation Matrix for Solution Providers and Measurement Barriers in Defense and Homeland Security

	Measurement Solution Barriers															
Solution Providers	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Calibration laboratories		_	_			Ť							- 0,		- 0,	
Commercial calibration service providers				1					1							
Component suppliers			1				1		1							
Contractor R&D labs-for-hire	1		2	1					1		1					
Engineering management/consulting firms/A&E firms								Ì	1							
Government laboratories and agencies	2		10	9	1	1	7		12	1	8	3		2		
Independent testing/certification laboratories																
Industrial R&D laboratories	1		3		1		2		2		3	1		1		
Industry consortium/partnership	1		1	1			2		3				1			
Instrument suppliers	3	1	7	4		1	4		6	1	4	3	1			
Material suppliers			1				1		1							
National Measurement Institute	4	1	16	11	1	3	9		13	1	9	3	1	3		
Small business/inventors																
Software developers			1	2					1		1	1				
Standards development organizations (SDOs)	1			2			1		5		2	1				
Testing laboratories																
Universities	1	1	7	2		1	2		2		4			1		

Exhibit 3.10: MN Correlation Matrix for Measurement Barriers and Measurement Solutions in Defense and Homeland Security

									M	eas	ure	me	nt S	Solu	ıtio	ns									
			Inf	rastru	ıctı	ire								F	Pro	duc	ts					9,	Serv	/ice	s
Measurement Solution Barriers	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Acceptability/Compatibility			1				3		1			2						1	1	· -	1				1
Accessibility			1						1										1						
Accuracy		1	6	2	1	2	3	2	4	2	7	5	3	3			1	2	2	2	1 ′		1		1
Data, Data Collection/and or																									
Retrieval		2	2	2	2	1	3		3	2	5	2	2		2			2	1	;	3				1
Destructive				1		1						1													
Expense		2						1	2	1	1				1				1						
Lack of Fundamental																									l
Knowledge			2	2		3	1	1	1	1	4	3	1	1	2		1				1				
Multiple Solutions Exist																									
Not Standardized			2	1	3	1	7	1	3	1	4	4	5	2	1			3			6		1		2
Production Readiness					1							1							1						
Reliability			3	2	1		3		1	1		6	4	3			1	1	2	2			1		1
Resolution			1	1			1		1	2	1		1		1						1				
Small Market Demand							1						1					1							
Speed		1	1							1	1	2			1										
System-Level Problem																									
Workforce																									

Exhibit 3.11: MN Correlation Matrix for Measurement Providers and Measurement Solutions in Defense and Homeland Security

										Mea	sur	eme	ent S	olu	tions	3									
			Infr	astru	ıctuı	e								Pro	oduc	cts						,	Serv	ices	
	Coordination/ facilitation	ta Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Measurement Solution Providers	ပိ	Data	De) Tec	Fui	Pro	Re	Sta	SN.	Cal	ဝိ	Me	Me	Me	Ra	Rei	Sof	Sta	Sta	Tes	Tes	Val	Cal	Ext	Inte	3rd
Calibration laboratories																									
Commercial calibration service providers									1		1				1										
Component suppliers						1		1			1														
Contractor R&D labs-for-hire							1				1	1						1			1				
Engineering management/consulting																									
firms/A&E firms					1													1		1					
Government laboratories and agencies		1	4	4	4	2	4		2	3	4	9	3	3	4		1	3	1	4	1		1		2
Independent testing/certification laboratories																									
Industrial R&D laboratories			2	1		1	1			1		3	2	1	1										1
Industry consortium/partnership			_			·	2		1		1		2					1		1					
Instrument suppliers			3	2	1	1	4	1	4	2	3	2	2	2			1	1	3	2					1
Material suppliers			- 0			1		1			1													-	
National Measurement Institute		2	6	3	4	2	7	1	5	3	7	9	6	2	4		1	4	3	6	1		1		2
Small business/inventors																									
Software developers				2					1	1			1					1							\neg
Standards development organizations (SDOs)			1		1		3					2	3							3					
Testing laboratories					·																				\dashv
Universities		1	3			1	2	1	2	1	3	4	1	1	1				1						

Exhibit 3.12: MN Correlation Matrix for Stage of Technological Innovation and Measurement Barriers in Defense and Homeland Security

					Me	easu	reme	nt S	olut	ion l	Barrie	ers				
Stage of Technological	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	peeds	System-Level Problem	Workforce
Applied Research	2	1	15			1	10	_	12	1	10		0,	2	- 0,	
Production	1		1			1			1							
Market	2		1	1					3				1			
End-use			1	1		1			1		1			1		

Exhibit 3.13: MN Correlation Matrix for Stage of Technological Innovation and Measurement Solutions in Defense and Homeland Security

									M	eas	ure	mei	nt S	olu	tio	าร								
			Inf	rastru	ctu	re								F	roc	luc	ts					Serv	vice	s
Stage of Technological Innovation	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	alida	9,	International Recognition	3rd Party Verification
Applied Research		1	6	4	2	3	6	1	5	3	8	10	5	3	3		1	2	2	;	3 ′			1
Production		·			1			1	1				·					1	1		1			
Market		·	1		1		2						1					1			2			1
End-use	·	1						Ť		1		1	1		1					, and the second		1		

Exhibit 3.14: MN Correlation Matrix for Solution Providers and Stage of Technological Innovation in Defense and Homeland Security

	_	Stage of Technologica Innovation					
Measurement Solution Providers	Applied Research	Production	Market	End-use			
Calibration laboratories							
Commercial calibration service providers	1						
Component suppliers	1						
Contractor R&D labs-for-hire	2						
Engineering management/consulting firms/A&E firms		1					
Government laboratories and agencies	18	1	2	2			
Independent testing/certification laboratories							
Industrial R&D laboratories	6						
Industry consortium/partnership	2		1				
Instrument suppliers	9	1	2				
Material suppliers	1						
National Measurement Institute	23	2	3	2			
Small business/inventors							
Software developers	2						
Standards development organizations (SDOs)	5						
Testing laboratories							
Universities	8						

Exhibit 3.15: MN Correlation Matrix for Stage of Technological Innovation and TI as Measurement Technology in Defense and Homeland Security

Stage of Technological Innovation	TI as Measurement Technology
Applied Research	17
Production	
Market	1
End-use	1

Exhibit 3.16: MN Correlation Matrix for TI as Measurement Technology and Measurement Barriers in Defense and Homeland Security

				1	Me	asu	reme	nt S	olut	ion l	Barrie	ers				
Innovation Equivalency	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Technology Innovation = Measurement Innovation		1	11	9		2	6		10	1	5	4		2		

Exhibit 3.17: MN Correlation Matrix for Solution Providers and TI as Measurement Technology in Defense and Homeland Security

Measurement Solution Providers	Technology Innovation =
Calibration laboratories	
Commercial calibration service providers	1
Component suppliers	1
Contractor R&D labs-for-hire	1
Engineering management/consulting firms/A&E firms	
Government laboratories and agencies	14
Independent testing/certification laboratories	
Industrial R&D laboratories	3
Industry consortium/partnership	1
Instrument suppliers	8
Material suppliers	1
National Measurement Institute	16
Small business/inventors	
Software developers	1
Standards development organizations (SDOs)	3
Testing laboratories	
Universities	4

Exhibit 3.18: MN Correlation Matrix for TI as Measurement Technology and Measurement Solutions in Defense and Homeland Security

										Ме	asuı	eme	ent S	Solu	tion	s									
			Infr	astr	uctu	ıre								Pro	oduc	ts							Serv	ices	i
Innovation Equivalency	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Technology Innovation = Measurement		0	4	0	0	_	_	_	4	0	0	0	0	0	0			_	•						4
Innovation		2	4	2	3	2	5	1	4	3	6	3	2	3	3		1	1	2	4	1				1

Exhibit 3.19: MN Correlation Matrix for Regulation as Driver/Barrier and Measurement Solutions in Defense and Homeland Security

										N	leas	urer	nen	t So	lutio	ons									
			Infr	astr	uctu	ure								Pro	oduc	cts							Ser	vice	S
Regulatory Issues	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Regulation is a Driver							2					2		1											1
Regulation is a Barrier		1								1					1										

Exhibit 3.20: MN Correlation Matrix for Solution Providers and Regulation as Driver/Barrier in Defense and Homeland Security

Measurement Solution Providers	Regulation is a Driver	Regulation is a Barrier
Calibration laboratories		
Commercial calibration service providers		
Component suppliers		
Contractor R&D labs-for-hire	1	
Engineering management/consulting firms/A&E firms		
Government laboratories and agencies	2	1
Independent testing/certification laboratories		
Industrial R&D laboratories	1	
Industry consortium/partnership		
Instrument suppliers		
Material suppliers		
National Measurement Institute	3	1
Small business/inventors		
Software developers		
Standards development organizations (SDOs)	1	
Testing laboratories		
Universities	1	

U.S. Measurement System

Measurement Need (MN) Data Book

Chapter 4. Electronics for Non-Semiconductor and Information Technology (IT) Hardware

Prepared by
Energetics Incorporated
for the
National Institute of Standards and Technology

April 2006

Reference List of MN Distribution Charts and MN Correlation Matrices

Distributi	on Charts	Page
Exhibit Nu	umber	
4.1	Measurement Barriers (Electronics for Non-Semiconductor and IT Hardware)	1
4.2	Solution Providers (Electronics for Non-Semiconductor and IT Hardware)	2
4.3	Measurement Solutions (Electronics for Non-Semiconductor and IT Hardware)	3
4.4	Magauranda (Flastronica for Non Comicanductor and IT Hardware)	1
4.5	Current Public/Private R&D Efforts (Electronics for Non-Semiconductor and IT Hardware)	5
4.6	TI as Measurement Technology (Electronics for Non-Semiconductor and IT Hardware)	6
4.7	Stage of Technological Innovation (Electronics for Non-Semiconductor and IT Hardware)	7
4.8	Regulation as Driver/Barrier (Electronics for Non-Semiconductor and IT Hardware)	8
Exhibit Nu		
4.9	Solution Providers – Measurement Barriers (Electronics for Non-Semiconductor and IT Hardware)	9
4.10	Measurement Barriers – Measurement Solutions (Electronics for Non-Semiconductor and IT Hardware)	10
4.11	Solution Providers – Measurement Solutions (Electronics for Non-Semiconductor and IT Hardware)	11
4.12	Stage of Technological Innovation – Measurement Barriers (Electronics for Non-Semiconductor and IT Hardware)	12
4.13	Stage of Technological Innovation – Measurement Solutions (Electronics for Non-Semiconductor and IT Hardware)	13
4.14	Solution Providers – Stage of Technological Innovation (Electronics for Non-Semiconductor and IT Hardware)	14
4.15	Stage of Tech. Innovation – TI as Measurement Tech. (Electronics for Non-Semiconductor and IT Hardware)	15
4.16	TI as Measurement Technology – Measurement Barriers (Electronics for Non-Semiconductor and IT Hardware)	16
4.17	Solution Providers – TI as Measurement Technology (Electronics for Non-Semiconductor and IT Hardware)	17
4.18	TI as Measurement Technology – Measurement Solutions (Electronics for Non-Semiconductor and IT Hardware)	18
4.19	Regulation as Driver/Barrier – Measurement Solutions (Electronics for Non-Semiconductor and IT Hardware)	
4.20	Solution Providers – Regulation as Driver/Barrier (Electronics for Non-Semiconductor and IT Hardware)	20

Exhibit 4.1: MN Distribution of Measurement Barriers in Electronics for Non-Semiconductor and IT Hardware

			Data Data			l aak af		Not				Consti		Cuete		
			Data, Data			Lack of		Not				Small		Syste		
			Collection			Fundamental	Multiple	Standardi	Production	Reliabil	Resolut	market		ms-		
Acceptibility	Accessibility	Accuracy	& Retrieval	Destructive	Expense	Knowledge	Solutions	zed	Readiness	ity	ion	demand	Speed	level	Workforce	Total
6	4	52	16	1	6	17	3	22	8	17	13	0	9	1	0	175

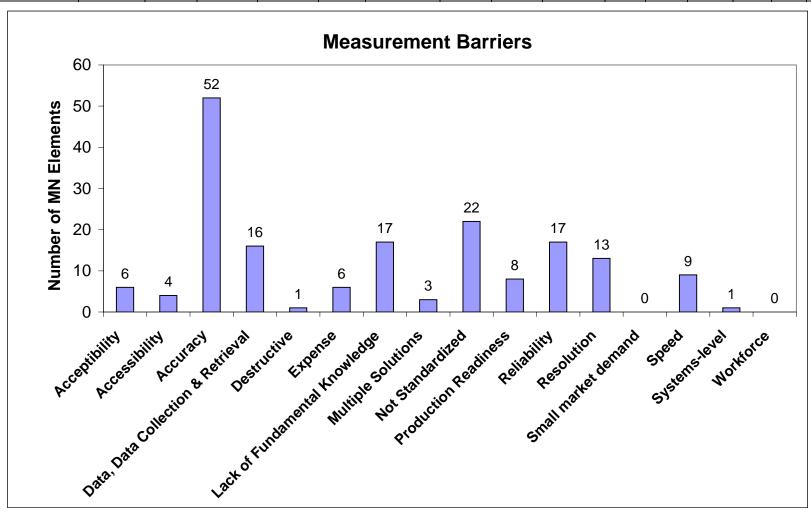


Exhibit 4.2: MN Distribution of Measurement Solution Providers in Electronics for Non-Semiconductor and IT Hardware

				Engineering													
	Commercial			Management/C		Independent								Standards			
	Calibration		Contractor	onsulting	Government	Testing/Certifica		Industry			National	Small		Development			
Calibration	Service	Component	R&D Labs-for-	Firms/A&E	Laboratories	tion	Industrial R&D	Consortium/	Instrument	Material	Measurement	Business/I	Software	Organizations	Testing		
Laboratories	Providers	Suppliers	Hire	Firms	and Agencies	Laboratories	Laboratories	Partnership	Suppliers	Suppliers	Institute	nventors	Developers	(SDO)	Laboratories	Universities	Total
1	0	13	2	0	69	2	27	20	31	2	50	0	3	9	0	40	269

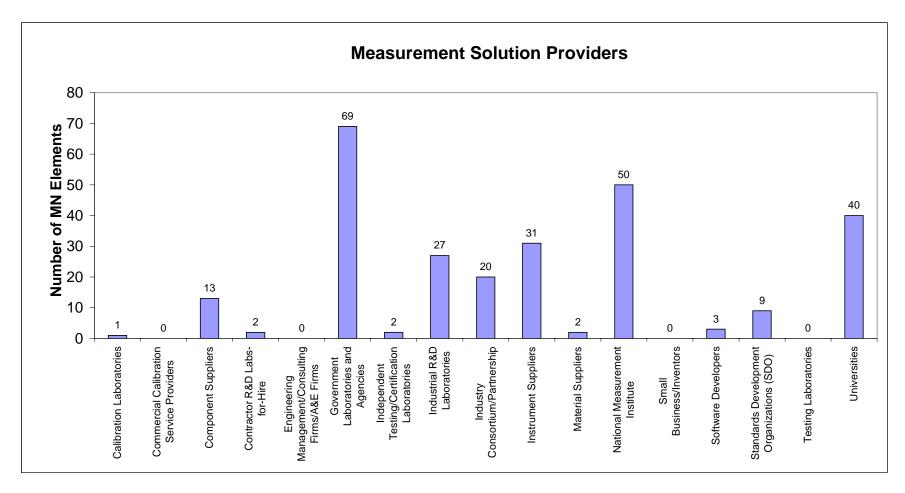


Exhibit 4.3: MN Distribution of Measurement Solutions in Electronics for Non-Semiconductor and IT Hardware

				Infrastruct	ure										Pro	ducts							Se	ervices		1
						Research -												Standard/ce		Test methods or	Validated					
Coo	ordinat	Data	Development -	Fund-		Measure-				Computati	Measure-	Measure-						rtified	Test methods for	test data for	(hardened)		Expert	Intl		
ion/	Facilit	Collection/R	Measurement	amental		ment	Standar	User	Calibra	onal	ment	ment	Metrics/Benc	Raw	Reference	Softw	Stability	reference	production-scale	consumer	properties	Calibrati	consulta	Recogniti	Third Party	
atio	n	etrieval	Technology	Knowledge	Protocols	Science	ds	Facility	tion	Methods	Instrument	Method	hmarks	Data	Data	are	Tests	material	measurements	products	data	on	tion	on	Verification	Total
	3	0	44	6	9	15	33	3	7	10	10	16	7	2	5	1	0	6	10	3	2	0	0	1	3	196

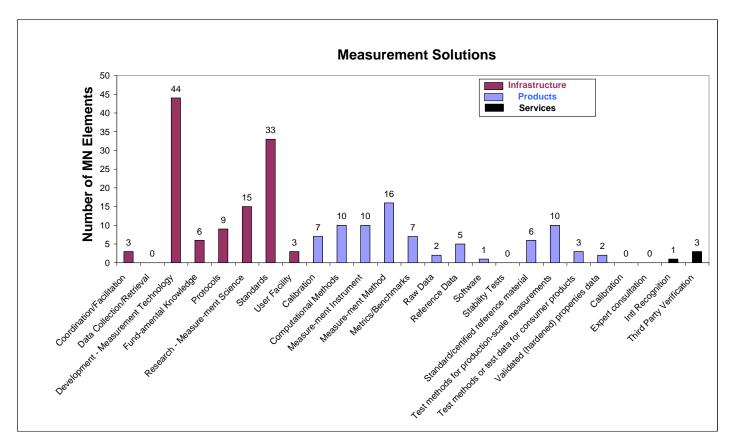


Exhibit 4.4: MN Distribution of Measurands in Electronics for Non-Semiconductor and IT Hardware

	Cla	ssical						Functiona	l					Performance			Structu	ural		
										Thermal-	Thermal-	Thermal-								
					Electronic/				Radio	Thermoch	Thermody	Thermoph	Computational	Software	System					
Biological	Chemical	Physical	Physiological	Acoustical	Electrical	Magnetic	Optical	Photonic	frequency	emical	namic	ysical	Performance	Performance	Performance	Kinetic	Mechanical	Molecular	Spatial	Total
0	5	27	1	0	20	9	5	4	4	0	2	2	2	0	7	0	3	2	1	94

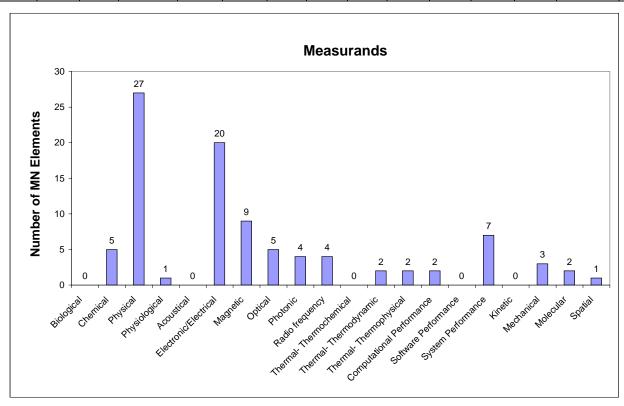


Exhibit 4.5: MN Distribution of Current Public/Private R&D Efforts in Electronics for Non-Semiconductor and IT Hardware

Only Private		Only Public		Both Public and	
Efforts Exist		Efforts Exist		Private Efforts Exist	No Efforts Exist
	24	5	5	35	30

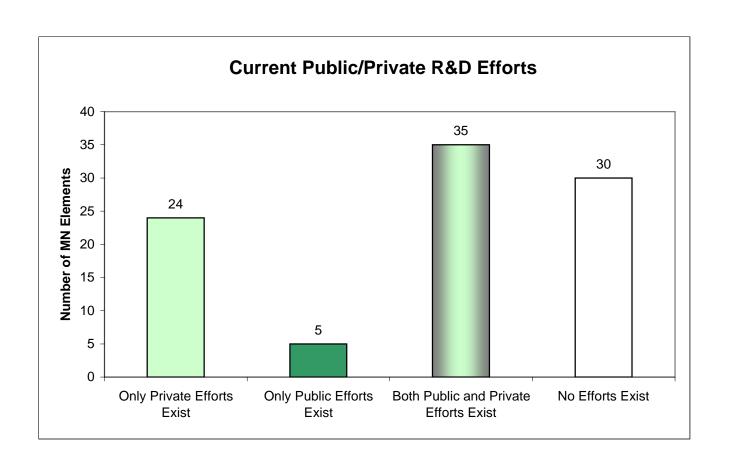


Exhibit 4.6: MN Distribution of TI as Measurement Technology in Electronics for Non-Semiconductor and IT Hardware

Technology	
Innovation is a	
Measurement	Technology Innovation is not a
Innovation	Measurement Innovation
21	73

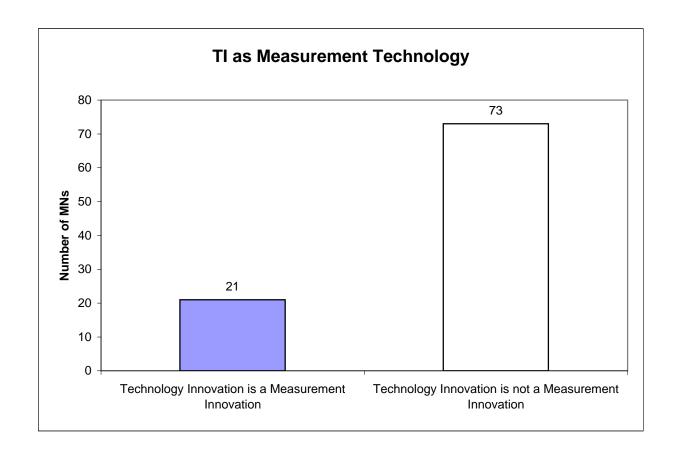


Exhibit 4.7: MN Distribution by Stage of Technological Innovation in Electronics for Non-Semiconductor and IT Hardware

Applied Research	Production	Market	End-use	Total
64	14	12	4	94

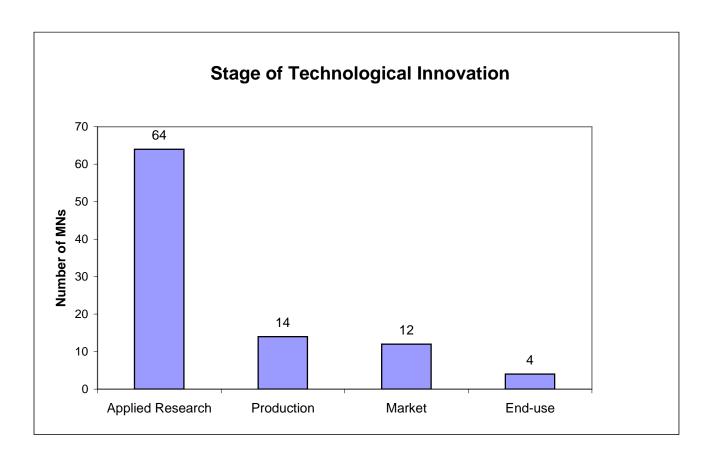


Exhibit 4.8: MN Distribution of Regulation as Driver/Barrier in Electronics for Non-Semiconductor and IT Hardware

MN Driver	MN Barrier	No Impact	
3	1	Ç	90

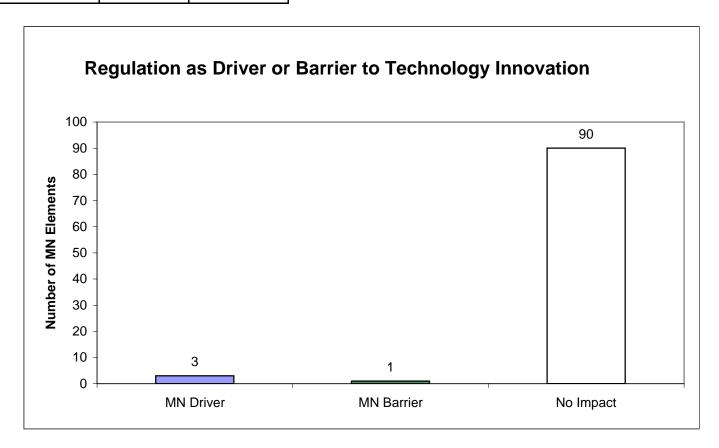


Exhibit 4.9: MN Correlation Matrix for Solution Providers and Measurement Barriers in Electronics for Non-Semiconductor and IT Hardware

				N	/leas	sure	men	t So	lutio	on B	arri	ers				
Solution Providers	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Calibration laboratories			1		_	1	_	_		_					-	
Commercial calibration service providers																
Component suppliers			8	2		2	1		6		4	3				
Contractor R&D labs-for-hire			2	1			1				1					
Engineering management/consulting firms/A&E firms																
Government laboratories and agencies	3	2	39	9		5	15	3	12	5	11	11		6	1	
Independent testing/certification laboratories	1			1					2		1					
Industrial R&D laboratories	1		10	2		1	9		9	1	3	3			1	
Industry consortium/partnership	1	3	12	5	1	3	2		4	1	6	4		7		
Instrument suppliers	3	2	15	5		1	3		6	6	6	5		2		
Material suppliers			1				1		1	1						
National Measurement Institute	5	4	29	9	1	3	5	3	10	6	8	5		6	1	
Small business/inventors																
Software developers			2		1						1			1		
Standards development organizations (SDOs)	2		3	3				1	3	1	1	1		1		
Testing laboratories																
Universities	1	1	25	10		2	12	2	8	3	7	7		3		

Exhibit 4.10: MN Correlation Matrix for Measurement Barriers and Measurement Solutions in Electronics for Non-Semiconductor and IT Hardware

									Me	eas	ure	mei	nt S	olu	ıtio	ns										
			Inf	rastru	ctu	ire								Р	roc	luc	ts						S	er\	/ice	S
Measurement Solution Barriers	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer	Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Acceptability/Compatibility	1		1	1	1	1	5					1	1					1	2		1				1	1
Accessibility	1				1		3		1		1	2														1
Accuracy	1		29	3	4	9	17	3	7	6	6	8	4		1			5	3	3	2					1
Data, Data Collection/and or																										
Retrieval	1		5		2	2	5	1	3	4	2	5	1	2	1			1	3	3	3	1				3
Destructive			1		1					1																
Expense			3			2	2		1		4	2	1					2								
Lack of Fundamental																										
Knowledge	1		8	6	1	8	3	1	1	2	3	3	2		2											
Multiple Solutions Exist			1					1	1		1	1	1	1												
Not Standardized	2		3		4	1	14	1	2	1	2	5	2	1	1	1		1	4		1	1			1	2
Production Readiness			6		1	1					1	1							2	2						
Reliability	1		6		2	2	4		3	5	3	3	2	1	1	1		2	4	1	1	2				1
Resolution			13	1		3	4	1		1	1	1		1					3	3						
Small Market Demand																										
Speed			8		2	2	3			1	3	3						2	1							
System-Level Problem							1																			
Workforce																										

Exhibit 4.11: MN Correlation Matrix for Measurement Providers and Measurement Solutions in Electronics for Non-Semiconductor and IT Hardware

										Mea	sur	eme	nt S	olut	tions	3									
			Infr	astru	ıctu	re								Pro	oduc	ets						,	Serv	ices	
	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Measurement Solution Providers	C	D		Ē	Ь	℃	Ś	0	ပ	ပ	Σ	Σ	Σ	8	~	S	Ś	Ś	ř	ř	>	ပ	Ш	드	ଞ
Calibration laboratories Commercial calibration service providers						- 1																			
Component suppliers			5			1	8	1	1		2	2	1					1	1						1
Contractor R&D labs-for-hire	1		3				0	•	1	1	1		1					•		1					
Engineering management/consulting	•									- '			•							- '					
firms/A&E firms																									
Government laboratories and agencies	2		36	5	3	11	22	2	3	6	7	10	7	2	4	1		4	5	3	2				1
Independent testing/certification laboratories	_		00	Ū						J	•		•	_	•	•					_				
inappendent tooming, continuation laboratories							1											1	2					1	1
Industrial R&D laboratories	1		12	2	1	8	8			4	1	5	3		4	1		1	2	1	1				
Industry consortium/partnership	1		11	1	4	3	7		3	3	5	3						2	4		1				2
Instrument suppliers	1		17	3		3	12	1	2	3	3	4	1						4	1					1
Material suppliers						1		1			1								1						
National Measurement Institute	1		20	1	6	8	21	2	5	4	6	11	3	2	2			5	3	1				1	2
Small business/inventors																									
Software developers			1		1					2		1	1						1						
Standards development organizations (SDOs)			4		2		4					1	1		1			1	3					1	
Testing laboratories																									
Universities	2		22	5	1	8	6	2	3	7	4	7	3	2	3	1		2	4	2	2				1

Exhibit 4.12: MN Correlation Matrix for Stage of Technological Innovation and Measurement Barriers in Electronics for Non-Semiconductor and IT Hardware

					Me	easu	reme	nt S	olut	ion l	Barrie	ers				
Stage of Technological Innovation	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Applied Research	2	3	38	10	1	5	14	1	12	5	13	8		8	1	
Production		1	7	2			1	, and the second	5	3	1	2	, and the second	·		
Market	4		5	3			1	2	4		1	3		1		
End-use			2	1		1	1	, and the second	1	,	2	·	, and the second	·		

Exhibit 4.13: MN Correlation Matrix for Stage of Technological Innovation and Measurement Solutions in Electronics for Non-Semiconductor and IT Hardware

									М	eas	ure	mer	nt S	olu	tior	าร										
			Inf	rastru	ıctι	ıre								Р	rod	luct	:S						S	erv	ice	S
Stage of Technological Innovation	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer	Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Applied Research	3		32	4	5	12	19	3	5	9	9	13	6	1	4	1		3	6		2	2				1
Production			5	1	1		6		1					1		-	1									1
Market			4	1	2	1	6			1	1	1	1	1				1	4		1				1	1
End-use			3		1	2	2		1			1						1								

Exhibit 4.14: MN Correlation Matrix for Solution Providers and Stage of Technological Innovation in Electronics for Non-Semiconductor and IT Hardware

	Stage of		nologi	cal
Measurement Solution Providers	Applied Research	Production	Market	End-use
Calibration laboratories			_	1
Commercial calibration service providers				
Component suppliers	5	5	2	1
Contractor R&D labs-for-hire	2			
Engineering management/consulting firms/A&E firms				
Government laboratories and agencies	48	12	7	2
Independent testing/certification laboratories	1		1	
Industrial R&D laboratories	22	3	1	1
Industry consortium/partnership	14	2	4	
Instrument suppliers	20	5	5	1
Material suppliers	2			
National Measurement Institute	36	5	6	3
Small business/inventors				
Software developers	2		1	
Standards development organizations (SDOs)		3	5	1
Testing laboratories				
Universities	32	5	3	

Exhibit 4.15: MN Correlation Matrix for Stage of Technological Innovation and TI as Measurement Technology in Electronics for Non-Semiconductor and IT Hardware

Stage of Technological Innovation	TI as Measurement Technology
Applied Research	17
Production	1
Market	2
End-use	1

Exhibit 4.16: MN Correlation Matrix for TI as Measurement Technology and Measurement Barriers in Electronics for Non-Semiconductor and IT Hardware

					Ме	asu	reme	nt S	olut	ion l	Barrie	ers				
Innovation Equivalency	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Technology Innovation = Measurement Innovation	1		11	4		3	5	1	5	2	5	1		1		

Exhibit 4.17: MN Correlation Matrix for Solution Providers and TI as Measurement Technology in Electronics for Non-Semiconductor and IT Hardware

Measurement Solution Providers	Technology Innovation = Measurement Innovation
Calibration laboratories	1
Commercial calibration service providers	
Component suppliers	2
Contractor R&D labs-for-hire	1
Engineering management/consulting firms/A&E firms	
Government laboratories and agencies	16
Independent testing/certification laboratories	
Industrial R&D laboratories	8
Industry consortium/partnership	2
Instrument suppliers	6
Material suppliers	1
National Measurement Institute	13
Small business/inventors	
Software developers	1
Standards development organizations (SDOs)	1
Testing laboratories	
Universities	7

Exhibit 4.18: MN Correlation Matrix for TI as Measurement Technology and Measurement Solutions in Electronics for Non-Semiconductor and IT Hardware

										M	eası	ıren	nent	Sol	utio	ns								
			Infr	astr	uctu	ıre								Р	rodu	ıcts						Ser	vice	s
Innovation Equivalency	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Technology Innovation = Measurement					_	4	7		0	4	_	_	0	4	0	,			0					
Innovation			4		2	4	- /	- 1	2	- 1	6	7	3	1	2	1		1	3		ı	<u> </u>		\perp

Exhibit 4.19: MN Correlation Matrix for Regulation as Driver/Barrier and Measurement Solutions in Electronics for Non-Semiconductor and IT Hardware

										N	leas	urei	nen	t So	lutio	ons									
			Infr	astı	ruct	ure								Pro	oduc	cts							Ser	vice	S
Regulatory Issues	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Regulation is a Driver	1		1	Ī	1	1	1		1			1	Ī		_	_		1			Ī	Ī	Ī	Ī	1
Regulation is a Barrier																		1	1					1	

Exhibit 4.20: MN Correlation Matrix for Solution Providers and Regulation as Driver/Barrier in Electronics for Non-Semiconductor and IT Hardware

Measurement Solution Providers	Regulation is a Driver	Regulation is a Barrier
Calibration laboratories	1	
Commercial calibration service providers		
Component suppliers		
Contractor R&D labs-for-hire		
Engineering management/consulting firms/A&E firms		
Government laboratories and agencies	1	
Independent testing/certification laboratories		1
Industrial R&D laboratories		
Industry consortium/partnership	2	
Instrument suppliers	1	
Material suppliers		
National Measurement Institute	3	1
Small business/inventors		
Software developers		
Standards development organizations (SDOs)		1
Testing laboratories		
Universities	1	

U.S. Measurement System

Measurement Need (MN) Data Book

Chapter 5. Electronics Semiconductor

Prepared by
Energetics Incorporated
for the
National Institute of Standards and Technology

April 2006

Reference List of MN Distribution Charts and MN Correlation Matrices

Distribut	tion Charts	Page
Exhibit No	lumber	
5.1	Measurement Barriers (Electronics Semiconductor)	1
5.2	Solution Providers (Electronics Semiconductor)	2
5.3	Measurement Solutions (Electronics Semiconductor)	3
5.4	Measurands (Electronics Semiconductor)	4
5.5	Current Public/Private R&D Efforts (Electronics Semiconductor)	5
5.6	IT as Measurement Technology (Electronics Semiconductor)	6
5.7	Stage of Technological Innovation (Electronics Semiconductor)	7
5.8	Regulation as Driver/Barrier (Electronics Semiconductor)	8
Correlation	ion Matrices	
5.9	Solution Providers – Measurement Barriers (Electronics Semiconductor)	٥
5.10		
5.11	Solution Providers – Measurement Solutions (Electronics Semiconductor)	
5.12	Stage of Technological Innovation – Measurement Barriers (Electronics Semiconductor)	
5.13	Stage of Technological Innovation – Measurement Solutions (Electronics Semiconductor)	
5.14	Solution Providers – Stage of Technological Innovation (Electronics Semiconductor)	1/
5.15		 15
5.16		16
5.17	Solution Providers – TI as Measurement Technology (Electronics Semiconductor)	17
5.18	TI as Measurement Technology – Measurement Solutions (Electronics Semiconductor)	18
5.19		19
5.20	Solution Providers – Regulation as Driver/Barrier (Electronics Semiconductor)	

Exhibit 5.1: MN Distribution of Measurement Barriers in Electronics Semiconductor

																i	ı
			Data, Data			Lack of		Not				Small		Syste			I
			Collection			Fundamental	Multiple	Standardi	Production	Reliabil	Resolut	market		ms-			
Acceptibility	Accessibility	Accuracy	& Retrieval	Destructive	Expense	Knowledge	Solutions	zed	Readiness	ity	ion	demand	Speed	level	Workforce	Total	
2	1	38	8	1	6	13	0	3	2	12	22	0	13	0	0	121	l

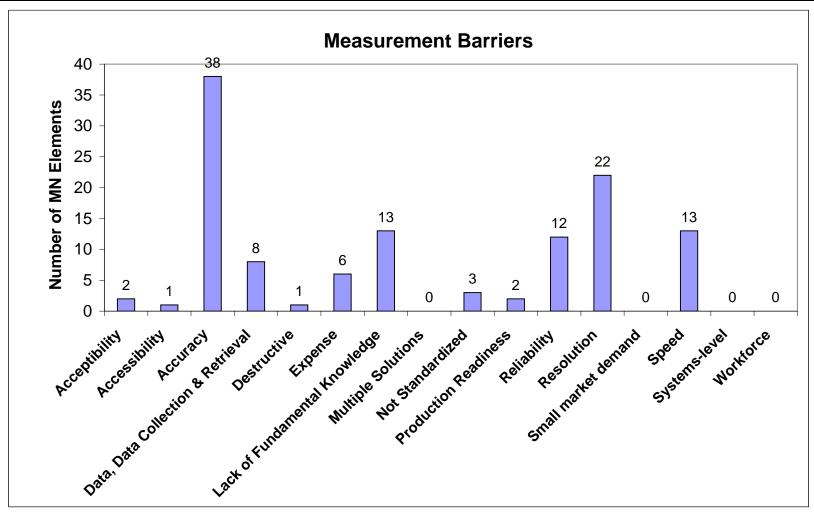


Exhibit 5.2: MN Distribution of Measurement Solution Providers in Electronics Semiconductor

				Engineering													
	Commercial			Management/C		Independent								Standards			
	Calibration		Contractor	onsulting	Government	Testing/Certifica		Industry			National	Small		Development			
Calibration	Service	Component	R&D Labs-for-	Firms/A&E	Laboratories	tion	Industrial R&D	Consortium/	Instrument	Material	Measurement	Business/I	Software	Organizations	Testing		
Laboratories	Providers	Suppliers	Hire	Firms	and Agencies	Laboratories	Laboratories	Partnership	Suppliers	Suppliers	Institute	nventors	Developers	(SDO)	Laboratories	Universities	Total
1	0	0	1	0	34	0	16	22	10	2	38	0	2	1	0	19	146

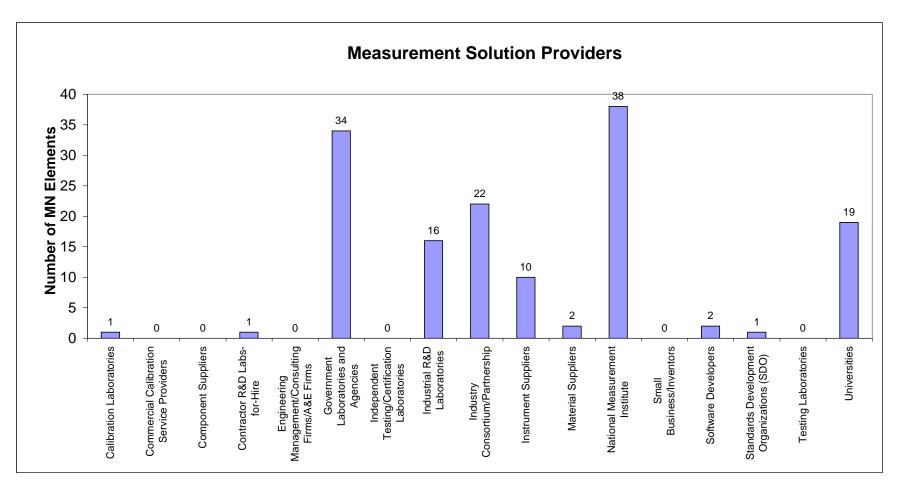


Exhibit 5.3: MN Distribution of Measurement Solutions in Electronics Semiconductor

				Infrastructu	ıre										Pro	ducts							S	ervices		<u> </u>
						Research -												Standard/ce		Test methods or	Validated					
	ordinat		Development -			Measure-				Computati	Measure-	Measure-							Test methods for		(hardened)			Intl		
ion	/Facilit	Collection/R	Measurement	amental		ment	Standar	User	Calibra	onal	ment	ment	Metrics/Benc	Raw	Reference	Softw	Stability	reference	production-scale	consumer	properties	Calibrati	consulta	Recogniti	Third Party	
atio	on	etrieval	Technology	Knowledge	Protocols	Science	ds	Facility	tion	Methods	Instrument	Method	hmarks	Data	Data	are	Tests	material	measurements	products	data	on	tion	on	Verification	Total
	0	0	31	2	2	12	8	5	7	10	16	13	1	3	2	1	0	7	6	0	1	1	1	0	1	130

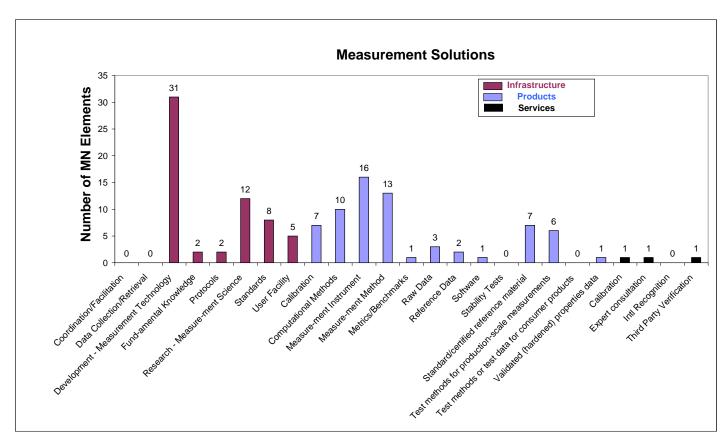


Exhibit 5.4: MN Distribution of Measurands in Electronics Semiconductor

		Clas	ssical						Functiona						Performance			Structi	ural		
											Thermal-	Thermal-	Thermal-								
						Electronic/				Radio	Thermoch	Thermody	Thermoph	Computational	Software	System					
Biolo	ogical	Chemical	Physical	Physiological	Acoustical	Electrical	Magnetic	Optical	Photonic	frequency	emical	namic	ysical	Performance	Performance	Performance	Kinetic	Mechanical	Molecular	Spatial	Total
(0	3	19	0	0	13	3	6	1	1	0	0	2	0	0	0	0	2	2	0	52

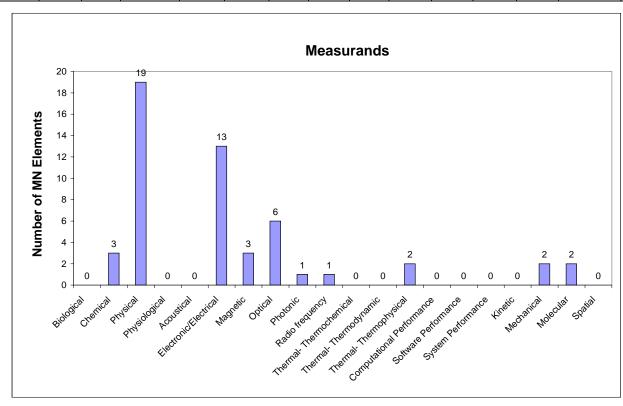


Exhibit 5.5: MN Distribution of Current Public/Private R&D Efforts in Electronics Semiconductor

1	- ,	Both Public and Private Efforts Exist	No Efforts Exist
4	2	15	31

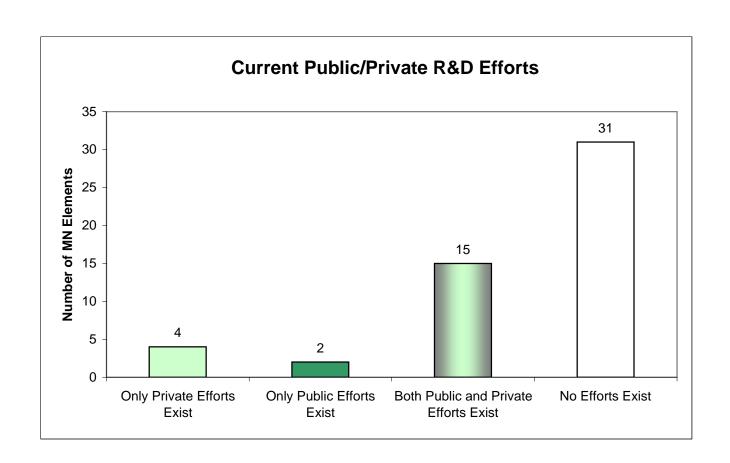


Exhibit 5.6: MN Distribution of TI as Measurement Technology in Electronics Semiconductor

Technology	
Innovation is a	
Measurement	Technology Innovation is not a
Innovation	Measurement Innovation
18	34

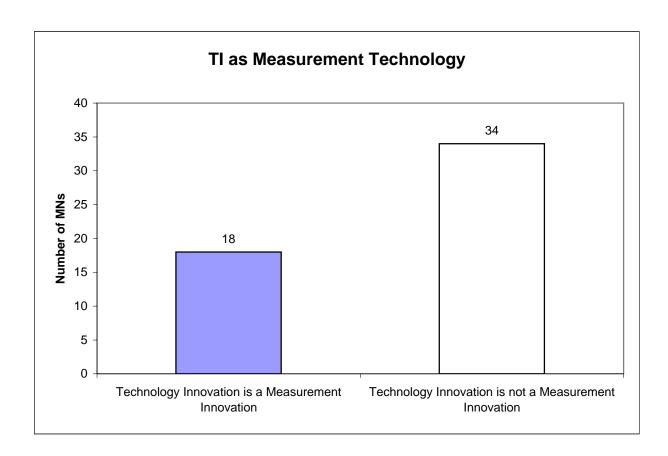


Exhibit 5.7: MN Distribution by Stage of Technological Innovation in Electronics Semiconductor

Applied Research	Production	Market	End-use	Total
44	6	1	1	52

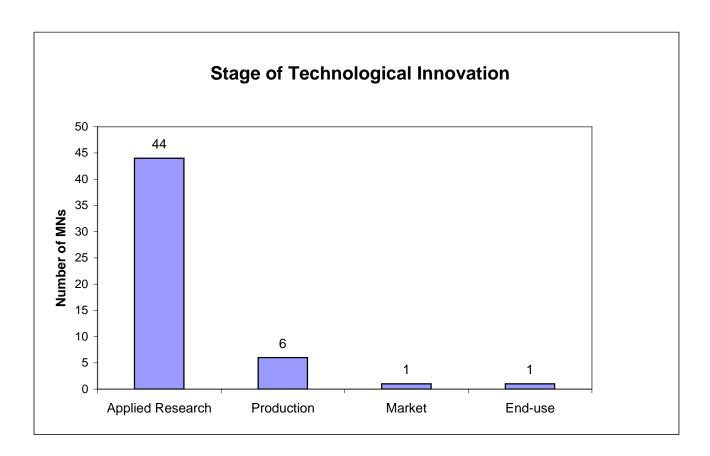


Exhibit 5.8: MN Distribution of Regulation as Driver/Barrier in Electronics Semiconductor

MN Driver	MN Barrier	No Impact	
2	0		50

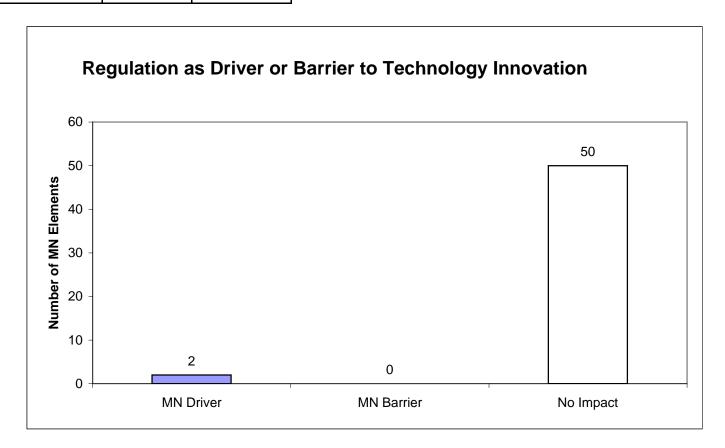


Exhibit 5.9: MN Correlation Matrix for Solution Providers and Measurement Barriers in Electronics Semiconductor

				N	/leas	sure	mer	t So	lutio	on B	arri	ers				
Solution Providers	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Calibration laboratories	_	_	1		_	1	_	_			_	-	- 0,	0,	<u> </u>	-
Commercial calibration service providers			·													
Component suppliers																
Contractor R&D labs-for-hire			1				1									
Engineering management/consulting firms/A&E firms																
Government laboratories and agencies			24	3		4	10		2	1	7	14		9		
Independent testing/certification laboratories																
Industrial R&D laboratories			9	1		1	2		1	2	3	6		2		
Industry consortium/partnership	1	1	18	3	1	2	8		1		4	10		10		
Instrument suppliers	2		8	2		3	3		1	1	3	4		1		
Material suppliers			1	1							1	2		1		
National Measurement Institute	1	1	29	7	1	4	8		2	1	9	18		10		
Small business/inventors																
Software developers			2		1							1		1		
Standards development organizations (SDOs)									1							
Testing laboratories																
Universities		1	13	5		2	4		1	1	5	8		5		

Exhibit 5.10: MN Correlation Matrix for Measurement Barriers and Measurement Solutions in Electronics Semiconductor

									M	eas	ure	mei	nt S	Solu	ıtio	ns										\Box
			Inf	rastru	ictu	ire								Р	roc	luc	s						S	erv	ice	S
Measurement Solution Barriers	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer	Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Acceptability/Compatibility			1			ш 0,	0,	1	1		1				_	٠,	0,	0,	1	Г	_				_	•
Accessibility									1			1														1
Accuracy			24	1	2	8	8	3	7	6	12	9	1	1	1			6	4	Į.			1	1		1
Data, Data Collection/and or																										
Retrieval			1				2	2	3	3	2	3		2	1			1	1							1
Destructive			1		1					1																
Expense			5			4	1	1	1		3							2	1							
Lack of Fundamental																										
Knowledge			9	2		4	1	1	2	4	7	1						1								
Multiple Solutions Exist																										
Not Standardized									1		1	1				1		1	1			1				
Production Readiness			2			1					1			1	1											
Reliability			5			3			3		3	3	1	2	1	1		2	1			1	1			
Resolution			17	1		7	3	2		6	7	6	1	1				2	3	3				1		
Small Market Demand																										
Speed			10		2	4	2	1		2	6	3						2	1							
System-Level Problem																										
Workforce																										

Exhibit 5.11: MN Correlation Matrix for Measurement Providers and Measurement Solutions in Electronics Semiconductor

										Mea	sur	eme	ent S	olu	tions	3									
			Infr	astru	ıctu	re								Pro	oduc	ts						,	Serv	ices	
	Coordination/ facilitation	a Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Measurement Solution Providers	ပိ	Data	Dev Tec	Fun	Pro	Res	Sta	Use	Cal	Cor	Mea	Mea	Met	Rav	Ref	Sof	Sta	Sta	Tes	Tes	Vali	Cal	Exp	Inte	3rd
Calibration laboratories			1			1												1							
Commercial calibration service providers																									
Component suppliers																									
Contractor R&D labs-for-hire									1	1	1														
Engineering management/consulting																									
firms/A&E firms																									
Government laboratories and agencies			23	2	1	10	6	1	2	6	9	7		3	1	1		5	4		1				
Independent testing/certification laboratories																									
Industrial R&D laboratories			8		1	2	2	1	1	1	2	7	1	1	1	1			3		1		1		
Industry consortium/partnership			16	1	2	7	2	1	3	3	11	3	1	-	1	- 1		3	1		-		•		1
Instrument suppliers			6	'		2	3	1	3	2	5	2	-	1	•				2						•
Material suppliers			1			1	1	1		1		1													
National Measurement Institute			22	1	1	9	6	5	6	8	12	10	1	1	1			6	3			1	1		1
Small business/inventors															•			J	J			•	•		•
Software developers			1		1					2		1													
Standards development organizations (SDOs)												1						1							
Testing laboratories																									
Universities			10	1		4	2	1	2	4	5	6		3	2	1		4	3		1				1

Exhibit 5.12: MN Correlation Matrix for Stage of Technological Innovation and Measurement Barriers in Electronics Semiconductor

					Me	asu	reme	ent S	olu	ion l	3arrie	ers				
Stage of Technological	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	ack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Applied Research	1	٧	32	6	1	<u>ш</u>	12		2	2	11	21	S	13	_O	_>
Production	1	1	5			1	1				1	1				
Market									1							
End-use			1			1					, and the second					

Exhibit 5.13: MN Correlation Matrix for Stage of Technological Innovation and Measurement Solutions in Electronics Semiconductor

									М	eas	ure	mer	nt S	olu	tior	าร									
			Inf	rastru	ıctι	ıre								Р	rod	luct	s					9,	erv	/ice	S
Stage of Technological Innovation	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Applied Research			27	2	2	11	7	4	5	9	15	11	1	3	1	1		4	5		1	1	1		
Production			3				1	1	2	1	1	1			1			1	1						1
Market												1						1							
End-use			1			1												1							

Exhibit 5.14: MN Correlation Matrix for Solution Providers and Stage of Technological Innovation in Electronics Semiconductor

	Stage of		nologi	cal
Measurement Solution Providers	Applied Research	Production	Market	End-use
Calibration laboratories				1
Commercial calibration service providers				
Component suppliers				
Contractor R&D labs-for-hire	1			
Engineering management/consulting firms/A&E firms				
Government laboratories and agencies	29	3	1	1
Independent testing/certification laboratories				
Industrial R&D laboratories	13	3		
Industry consortium/partnership	19	3		
Instrument suppliers	9	1		
Material suppliers	2			
National Measurement Institute	31	5	1	1
Small business/inventors				
Software developers	2			
Standards development organizations (SDOs)			1	
Testing laboratories				
Universities	17	2		

Exhibit 5.15: MN Correlation Matrix for Stage of Technological Innovation and TI as Measurement Technology in Electronics Semiconductor

Stage of Technological Innovation	TI as Measurement Technology
Applied Research	17
Production	
Market	
End-use	1

Exhibit 5.16: MN Correlation Matrix for TI as Measurement Technology and Measurement Barriers in Electronics Semiconductor

					Me	asu	reme	nt S	olut	ion l	Barrie	ers				
Innovation Equivalency	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Technology Innovation = Measurement Innovation			14	3		3	3		1	1	6	9		1		

Exhibit 5.17: MN Correlation Matrix for Solution Providers and TI as Measurement Technology in Electronics Semiconductor

Measurement Solution Providers	Technology Innovation = Measurement Innovation
Calibration laboratories	1
Commercial calibration service providers	
Component suppliers	
Contractor R&D labs-for-hire	1
Engineering management/consulting firms/A&E firms	
Government laboratories and agencies	11
Independent testing/certification laboratories	
Industrial R&D laboratories	6
Industry consortium/partnership	1
Instrument suppliers	5 2
Material suppliers	2
National Measurement Institute	13
Small business/inventors	
Software developers	1
Standards development organizations (SDOs)	
Testing laboratories	
Universities	7

Exhibit 5.18: MN Correlation Matrix for TI as Measurement Technology and Measurement Solutions in Electronics Semiconductor

										Ме	asu	rem	ent	Solu	utior	าร									
			Infr	astr	uctu	ıre								Pr	odu	cts						;	Serv	ices	;
Innovation Equivalency	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Technology Innovation = Measurement			40			_	_	0		_		•						_	•				1		
Innovation	oxdot		10			5	5	2	2	5	4	6		1		1		2	2		1	1	1		

Exhibit 5.19: MN Correlation Matrix for Regulation as Driver/Barrier and Measurement Solutions in Electronics Semiconductor

										N	leas	urei	men	t So	lutio	ons									
			Infr	ast	ruct	ure								Pro	odu	cts							Ser	vice	s
Regulatory Issues Regulation is a Driver	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Regulation is a Barrier									•																•

Exhibit 5.20: MN Correlation Matrix for Solution Providers and Regulation as Driver/Barrier in Electronics Semiconductor

Measurement Solution Providers	Regulation is a Driver	Regulation is a Barrier
Calibration laboratories	1	
Commercial calibration service providers		
Component suppliers		
Contractor R&D labs-for-hire		
Engineering management/consulting firms/A&E firms		
Government laboratories and agencies	1	
Independent testing/certification laboratories		
Industrial R&D laboratories		
Industry consortium/partnership	1	
Instrument suppliers		
Material suppliers		
National Measurement Institute	2	
Small business/inventors		
Software developers		
Standards development organizations (SDOs)		
Testing laboratories		
Universities	1	

U.S. Measurement System

Measurement Need (MN) Data Book

Chapter 6. Energy, Power, and Environment

(includes Fossil fuel, Hydrogen, Renewable, and Power Generation and Distribution)

Prepared by
Energetics Incorporated
for the
National Institute of Standards and Technology

April 2006

Reference List of MN Distribution Charts and MN Correlation Matrices

Distributi	ion Charts	Page
Exhibit No	umber	
6.1	Measurement Barriers (Energy, Power, and Environment)	1
6.2	Solution Providers (Energy, Power, and Environment)	2
6.3	Measurement Solutions (Energy, Power, and Environment)	3
6.4	Measurands (Energy, Power, and Environment)	4
6.5	Measurands (Energy, Power, and Environment) Current Public/Private R&D Efforts (Energy, Power, and Environment)	5
6.6	IT as Measurement Technology (Energy, Power, and Environment)	6
6.7	Stage of Technological Innovation (Energy, Power, and Environment)	7
6.8	Regulation as Driver/Barrier (Energy, Power, and Environment)	8
Correlation	on Matrices umber	
6.9	Solution Providers – Measurement Barriers (Energy, Power, and Environment)	9
6.10	Measurement Barriers – Measurement Solutions (Energy, Power, and Environment)	10
6.11	Solution Providers – Measurement Solutions (Energy, Power, and Environment)	11
6.12	Solution Providers – Measurement Solutions (Energy, Power, and Environment) Stage of Technological Innovation – Measurement Barriers (Energy, Power, and Environment)	12
6.13	Stage of Technological Innovation – Measurement Solutions (Energy, Power, and Environment)	13
6.14	Solution Providers – Stage of Technological Innovation (Energy, Power, and Environment)	14
6.15	Solution Providers – Stage of Technological Innovation (Energy, Power, and Environment) Stage of Technological Innovation – TI as Measurement Technology (Energy, Power, and Environment)	15
6.16	TI as Measurement Technology – Measurement Barriers (Energy, Power, and Environment)	16
6.17	Solution Providers – TI as Measurement Technology (Energy, Power, and Environment)	17
6.18	Solution Providers – TI as Measurement Technology (Energy, Power, and Environment) TI as Measurement Technology – Measurement Solutions (Energy, Power, and Environment)	18
6.19	Regulation as Driver/Barrier – Measurement Solutions (Energy, Power, and Environment)	19
6.20	Solution Providers – Regulation as Driver/Barrier (Energy, Power, and Environment)	20

Exhibit 6.1: MN Distribution of Measurement Barriers in Energy, Power, and Environment

			Data, Data			Lack of		Not				Small		Syste		
			Collection			Fundamental	Multiple	Standardi	Production	Reliabil	Resolut	market		ms-		
Acceptibility	Accessibility	Accuracy	& Retrieval	Destructive	Expense	Knowledge	Solutions	zed	Readiness	ity	ion	demand	Speed	level	Workforce	Total
1	1	14	15	1	0	7	1	9	1	7	3	0	2	0	0	62

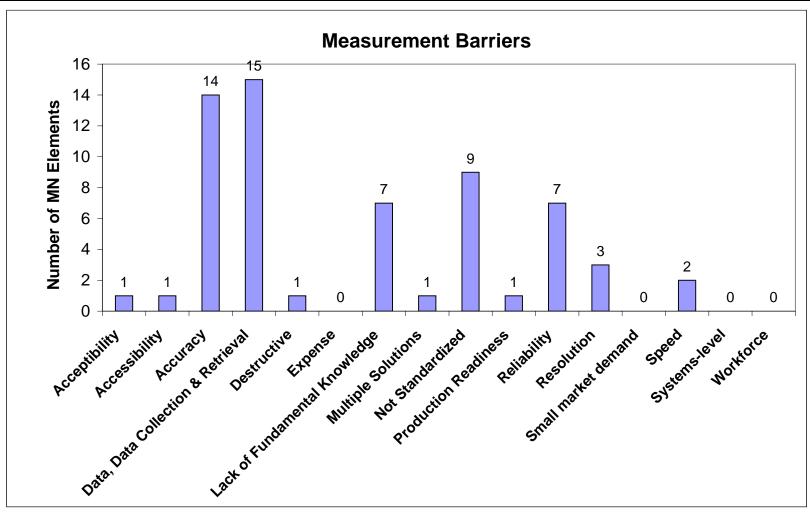


Exhibit 6.2: MN Distribution of Measurement Solution Providers in Energy, Power, and Environment

				Engineering													
	Commercial			Management/C		Independent								Standards			
	Calibration		Contractor	onsulting	Government	Testing/Certifica		Industry			National	Small		Development			
Calibration	Service	Component	R&D Labs-for-	Firms/A&E	Laboratories	tion	Industrial R&D	Consortium/	Instrument	Material	Measurement	Business/I	Software	Organizations	Testing		
Laboratories	Providers	Suppliers	Hire	Firms	and Agencies	Laboratories	Laboratories	Partnership	Suppliers	Suppliers	Institute	nventors	Developers	(SDO)	Laboratories	Universities	Total
3	1	1	0	0	18	2	10	2	3	2	20	0	1	3	0	8	74

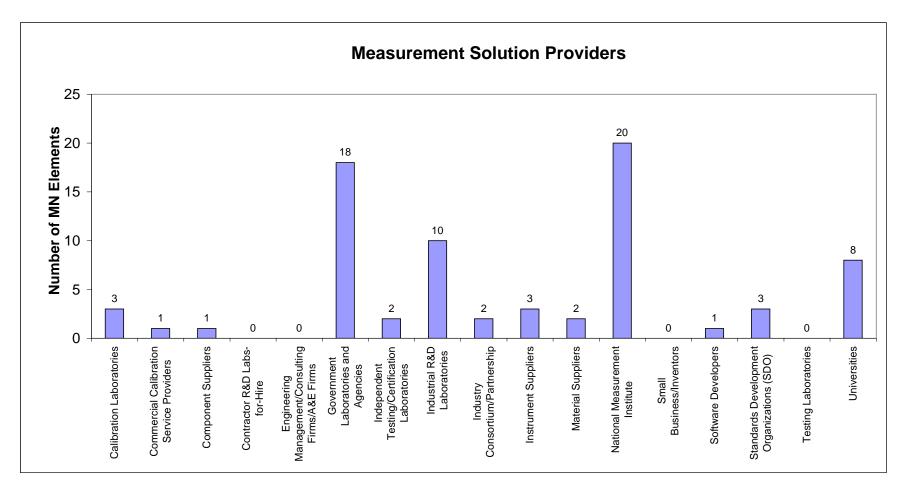


Exhibit 6.3: MN Distribution of Measurement Solutions in Energy, Power, and Environment

			Infrastruct	ure										Proc	ducts							S	ervices		1
					Research -												Standard/ce		Test methods or	Validated					
Coord	nat Data	Development -	Fund-		Measure-				Computati	Measure-	Measure-						rtified	Test methods for	test data for	(hardened)		Expert	Intl		
ion/Fa	ilit Collection/F	Measurement	amental		ment	Standar	User	Calibra	onal	ment	ment	Metrics/Benc	Raw	Reference	Softw	Stability	reference	production-scale	consumer	properties	Calibrat	consulta	Recognit	Third Party	
ation	etrieval	Technology	Knowledge	Protocols	Science	ds	Facility	tion	Methods	Instrument	Method	hmarks	Data	Data	are	Tests	material	measurements	products	data	on	tion	on	Verification	Total
2	1	7	3	1	5	7	3	7	6	2	6	2	4	3	0	0	2	6	1	1	1	0	1	1	72

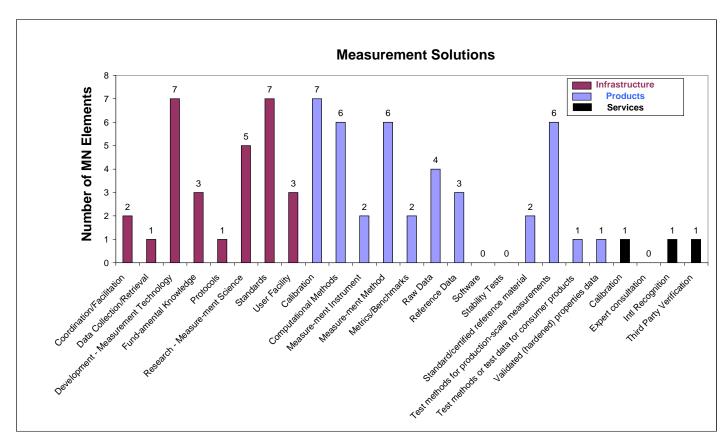


Exhibit 6.4: MN Distribution of Measurands in Energy, Power, and Environment

		Cla	ssical						Functiona	I					Performance			Structu	ıral		
Г											Thermal-	Thermal-	Thermal-								
						Electronic/				Radio	Thermoch	Thermody	Thermoph	Computational	Software	System					
	Biological	Chemical	Physical	Physiological	Acoustical	Electrical	Magnetic	Optical	Photonic	frequency	emical	namic	ysical	Performance	Performance	Performance	Kinetic	Mechanical	Molecular	Spatial	Total
	0	4	5	1	1	6	2	2	1	0	2	1	1	0	0	0	0	1	0	0	27

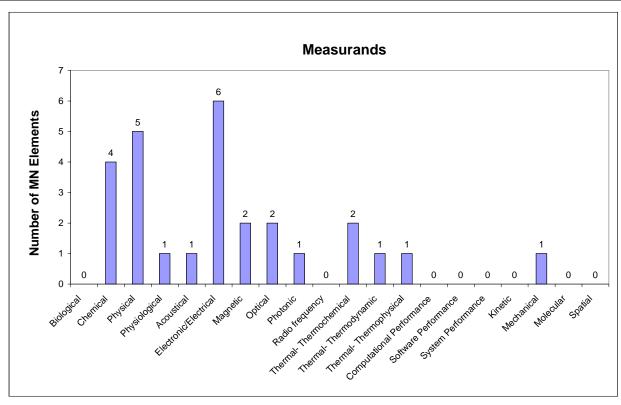


Exhibit 6.5: MN Distribution of Current Public/Private R&D Efforts in Energy, Power, and Environment

Only Private Efforts Exist	Only Public Efforts Exist	Both Public and Private Efforts Exist	No Efforts Exist
		_	
2	2 7	7 5	13

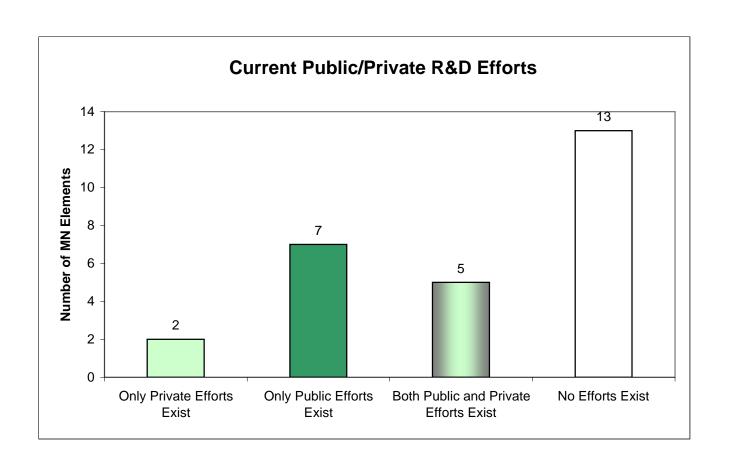


Exhibit 6.6: MN Distribution of TI as Measurement Technology in Energy, Power, and Environment

	<u> </u>
Technology	
Innovation is a	
Measurement	Technology Innovation is not a
Innovation	Measurement Innovation
11	16

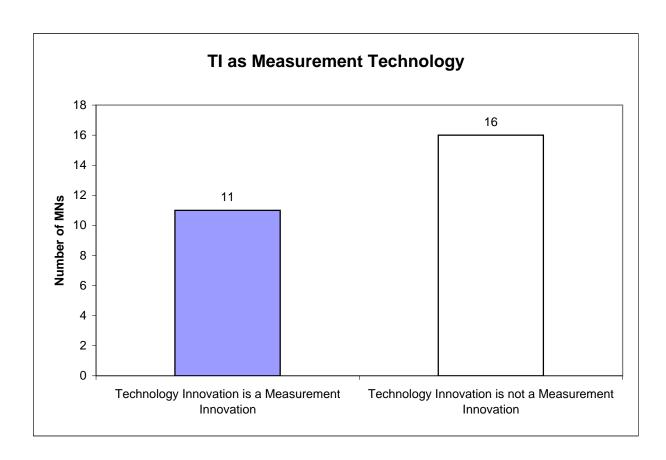


Exhibit 6.7: MN Distribution by Stage of Technological Innovation in Energy, Power, and Environment

Applied Research	Production	Market	End-use	Total
19	3	4	1	27

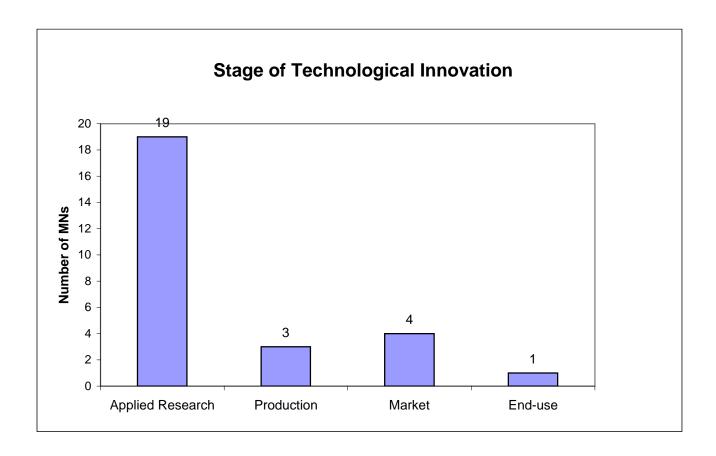


Exhibit 6.8: MN Distribution of Regulation as Driver/Barrier in Energy, Power, and Environment

MN Driver	MN Barrier	No Impact
0	2	25

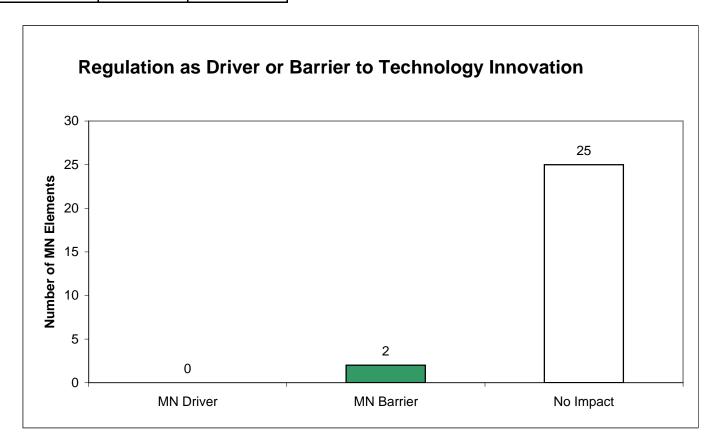


Exhibit 6.9: MN Correlation Matrix for Solution Providers and Measurement Barriers in Energy, Power, and Environment

				N	/leas	sure	men	t So	lutio	on B	arri	ers				
Solution Providers	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Calibration laboratories	1		3	1					1							
Commercial calibration service providers				1					1							
Component suppliers				1					1		1					
Contractor R&D labs-for-hire																
Engineering management/consulting firms/A&E firms																
Government laboratories and agencies		1	8	9	1		7	1	6	1	2	2		1		
Independent testing/certification laboratories	1		1	1					1		1					
Industrial R&D laboratories			4	6	1		5		3	1	2			1		
Industry consortium/partnership				2					1		1					
Instrument suppliers			2	2					2		1	1				
Material suppliers		1	1	1					1			1		1		
National Measurement Institute	1		11	11	1		5	1	5	1	6	2		2		
Small business/inventors																
Software developers				1					1			1				
Standards development organizations (SDOs)		1	2	1					2							
Testing laboratories																
Universities			5	6			2	1			3	1		1		

Exhibit 6.10: MN Correlation Matrix for Measurement Barriers and Measurement Solutions in Energy, Power, and Environment

									Me	eas	ure	me	nt S	Solu	ıtio	ns									
			Inf	rastru	ιctι	ire								Р	roc	luc	ts					,	Serv	/ice	es:
Measurement Solution Barriers	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Acceptability/Compatibility				ш х	4	E 07	1	Н	1	0	_	_	_	<u> </u>	<u> </u>	0)	0)	0)	F 0		+-	+	۳	1	<u>ب</u>
Accessibility	1						·		•			1						1					1	_	
Accuracy	1		5	1	1	4	4	2	5	2		3		3				2	2			1		1	
Data, Data Collection/and or																									
Retrieval	1	1	2	1		3	4	3	3	6	2	4	1	4	1			1	4		٠ ا				1
Destructive	1										1	1													
Expense																									
Lack of Fundamental																									
Knowledge	1	1	3	2		2	1			1	1	1		1	2				3						
Multiple Solutions Exist			1					1	1																
Not Standardized	1			1	1	1	5		3	1	1	1	1	1	1			1	3	•	'				1
Production Readiness			1	1															1						
Reliability			3	1	1	2	3		3	2		1		1				1	2						1
Resolution			1	1				2	1	2		1		1											Ш
Small Market Demand																					1				Ш
Speed								1		1		2									1				Ш
System-Level Problem																					1				Ш
Workforce																									

Exhibit 6.11: MN Correlation Matrix for Measurement Providers and Measurement Solutions in Energy, Power, and Environment

										Mea	sur	eme	ent S	olu	tions	3									
			Infr	astru	ıctuı	re								Pro	oduc	ets						,	Serv	ices	
Measurement Solution Providers	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Calibration laboratories	ပ	□		ь	Ь	~	თ	_	<u>ن</u>	Ö	2	2	2	1	~	တ	S	S	1	F	>	<u>ن</u>	Ш	<u>-</u>	ଳ
Commercial calibration service providers									1		1				1				- '					- '	
Component suppliers							1		-		•				•				1						1
Contractor R&D labs-for-hire							•												•						_
Engineering management/consulting																									
firms/A&E firms																									
Government laboratories and agencies	2	1	6	3		3	3	2	4	2	2	3	1	2	3			1	4	1	1	1			
Independent testing/certification laboratories		•		J			Ŭ			_			•	_	Ū			•		•	•	•			
inacpondon toomigroominoation laboratories							2		1										1					1	1
Industrial R&D laboratories	1	1	2	2		4	2		- 1	2	1	2	1	1				1	3	1	1				-
Industry consortium/partnership	-	•				-	1			1	•	1	1	•				•	1		•				1
Instrument suppliers			1	1		1	1		2	1			•	1					1						
Material suppliers	1		•			-	- 1	1		1		2						1	-						
National Measurement Institute	1		6	1	1	3	6	3	6	4	2	5	1	3	3			1	4	1	1	1		1	
Small business/inventors	•				•					•	_				J					- 1					
Software developers				1					1	1															
Standards development organizations (SDOs)	1					1						1	1					1	1						
Testing laboratories																									
Universities		1	3	1		2	1	2	2	5		3	1	2				1							

Exhibit 6.12: MN Correlation Matrix for Stage of Technological Innovation and Measurement Barriers in Energy, Power, and Environment

					Me	asu	reme	nt S	olut	ion l	Barrie	ers				
Stage of Technological Innovation	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Applied Research			9	12	1		6	1	6		5	3		2		
Production		1	2				1		1	1	1					
Market	1		2	3					1							
End-use			1						1		1					

Exhibit 6.13: MN Correlation Matrix for Stage of Technological Innovation and Measurement Solutions in Energy, Power, and Environment

									М	eas	urei	mer	nt S	olu	tior	าร										
			Inf	rastrı	ıctι	ıre								Р	rod	uct	:S						S	erv	ice	s
Stage of Technological Innovation	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer	roducts	alidated D	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Applied Research	1	1	6	2		4	1 4	3	5	5	2	4	1	4	3			1	4							1
Production	1		1	1								1						1	1				1			
Market		Ť					1 2		1	1		1	1	•					1		1	1			1	
End-use					1		1		1																	

Exhibit 6.14: MN Correlation Matrix for Solution Providers and Stage of Technological Innovation in Energy, Power, and Environment

	Stage of		nologi	cal
Measurement Solution Providers	Applied Research	Production	Market	End-use
Calibration laboratories	1	1	1	
Commercial calibration service providers	1			
Component suppliers	1			
Contractor R&D labs-for-hire				
Engineering management/consulting firms/A&E firms				
Government laboratories and agencies	13	3	2	
Independent testing/certification laboratories	1		1	
Industrial R&D laboratories	7	1	2	
Industry consortium/partnership	1		1	
Instrument suppliers	3			
Material suppliers	1	1		
National Measurement Institute	14	2	3	1
Small business/inventors				
Software developers	1			
Standards development organizations (SDOs)	1	1	1	
Testing laboratories				
Universities	7		1	

Exhibit 6.15: MN Correlation Matrix for Stage of Technological Innovation and TI as Measurement Technology in Energy, Power, and Environment

Stage of Technological	Tl as Measurement Technology
Innovation	Te
Applied Research	9
Production	1
Market	1
End-use	

Exhibit 6.16: MN Correlation Matrix for TI as Measurement Technology and Measurement Barriers in Energy, Power, and Environment

					Me	asu	reme	nt S	olut	ion I	3arrie	rs				
Innovation Equivalency	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Technology Innovation = Measurement Innovation	1		6	5			2		4		2	2		2		

Exhibit 6.17: MN Correlation Matrix for Solution Providers and TI as Measurement Technology in Energy, Power, and Environment

Measurement Solution Providers	Technology Innovation = ω Measurement Innovation
Calibration laboratories	3
Commercial calibration service providers	1
Component suppliers	
Contractor R&D labs-for-hire	
Engineering management/consulting firms/A&E firms	
Government laboratories and agencies	7
Independent testing/certification laboratories	1
Industrial R&D laboratories	2
Industry consortium/partnership	
Instrument suppliers	3
Material suppliers	1
National Measurement Institute	10
Small business/inventors	
Software developers	1
Standards development organizations (SDOs)	
Testing laboratories	
Universities	2

Exhibit 6.18: MN Correlation Matrix for TI as Measurement Technology and Measurement Solutions in Energy, Power, and Environment

										Ме	asu	rem	ent S	Solu	ıtion	ıs									
			Infr	astr	uctu	ıre								Pre	odu	cts						;	Serv	ices	
Innovation Equivalency	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Technology Innovation = Measurement			_			_		1	_			_		1	_				•						
Innovation	<u> </u>		2	1		2	4	1	5	2	1	2		1	2				2			1		1	

Exhibit 6.19: MN Correlation Matrix for Regulation as Driver/Barrier and Measurement Solutions in Energy, Power, and Environment

										N	leas	urei	nen	t So	lutio	ons									
			Infr	astr	uct	ure								Pro	odu	cts							Ser	vice	S
Regulatory Issues	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Regulation is a Driver							0		1					1					1					4	
Regulation is a Barrier							2		1					1					1					1	

Exhibit 6.20: MN Correlation Matrix for Solution Providers and Regulation as Driver/Barrier in Energy, Power, and Environment

Measurement Solution Providers	Regulation is a Driver	Regulation is a Barrier
Calibration laboratories		2
Commercial calibration service providers		-
Component suppliers		
Contractor R&D labs-for-hire		
Engineering management/consulting firms/A&E firms		
Government laboratories and agencies		
Independent testing/certification laboratories		1
Industrial R&D laboratories		
Industry consortium/partnership		
Instrument suppliers		1
Material suppliers		
National Measurement Institute		2
Small business/inventors		
Software developers		
Standards development organizations (SDOs)		
Testing laboratories		
Universities		

U.S. Measurement System

Measurement Need (MN) Data Book

Chapter 7. Healthcare

(includes Bioimaging and Informatics, Clinical Diagnostics, Health and Safety, and Pharmaceuticals)

Prepared by
Energetics Incorporated
for the
National Institute of Standards and Technology

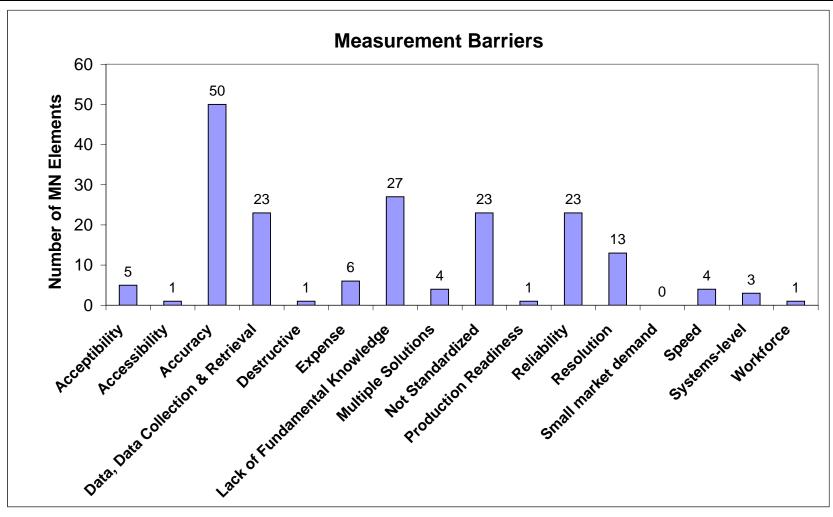
April 2006

Reference List of MN Distribution Charts and MN Correlation Matrices

Distribut	ition Charts	Page
Exhibit No	Number	_
7.1	Measurement Barriers (Healthcare)	1
7.2	Solution Providers (Healthcare)	2
7.3	Measurement Solutions (Healthcare) Measurands (Healthcare)	3
7.4		
7.5	Current Public/Private R&D Efforts (Healthcare) TLas Measurement Technology (Healthcare)	5
7.6		
7.7	Stage of Technological Innovation (Healthcare)	7
7.8	Regulation as Driver/Barrier (Healthcare)	8
Exhibit No		
7.9	Solution Providers – Measurement Barriers (Healthcare)	9
7.10		10
7.11	Solution Providers – Measurement Solutions (Healthcare)	11
7.12		12
7.13	Stage of Technological Innovation – Measurement Solutions (Healthcare)	13
7.14	O a lostina a Dana del anno a Company de Translando a los aires titano de la latina anno la	4.4
7.15		15
7.16	TI as Measurement Technology – Measurement Barriers (Healthcare)	16
7.17	Solution Providers – TI as Measurement Technology (Healthcare)	17
7.18	II as Measurement Technology – Measurement Solutions (Healthcare)	18
7.19	Regulation as Driver/Barrier – Measurement Solutions (Healthcare)	19
7.20	Solution Providers – Regulation as Driver/Barrier (Healthcare)	20

Exhibit 7.1: MN Distribution of Measurement Barriers in Healthcare

																ĺ		İ
				Data, Data			Lack of		Not				Small		Syste	1		İ
				Collection			Fundamental	Multiple	Standardi	Production	Reliabil	Resolut	market		ms-	Workforc	1	İ
Α	cceptibility	Accessibility	Accuracy	& Retrieval	Destructive	Expense	Knowledge	Solutions	zed	Readiness	ity	ion	demand	Speed	level	е	Total	İ
	5	1	50	23	1	6	27	4	23	1	23	13	0	4	3	1	185	İ



1

Exhibit 7.2: MN Distribution of Measurement Solution Providers in Healthcare

				Engineering													
	Commercial			Management/C		Independent								Standards			
	Calibration		Contractor	onsulting	Government	Testing/Certifica	ı	Industry			National	Small		Development			
Calibration	Service	Component	R&D Labs-for-	Firms/A&E	Laboratories	tion	Industrial R&D	Consortium/	Instrument	Material	Measurement	Business/I	Software	Organizations	Testing		
Laboratories	Providers	Suppliers	Hire	Firms	and Agencies	Laboratories	Laboratories	Partnership	Suppliers	Suppliers	Institute	nventors	Developers	(SDO)	Laboratories	Universities	Total
1	0	2	0	1	55	2	25	16	16	2	59	0	2	11	1	27	220

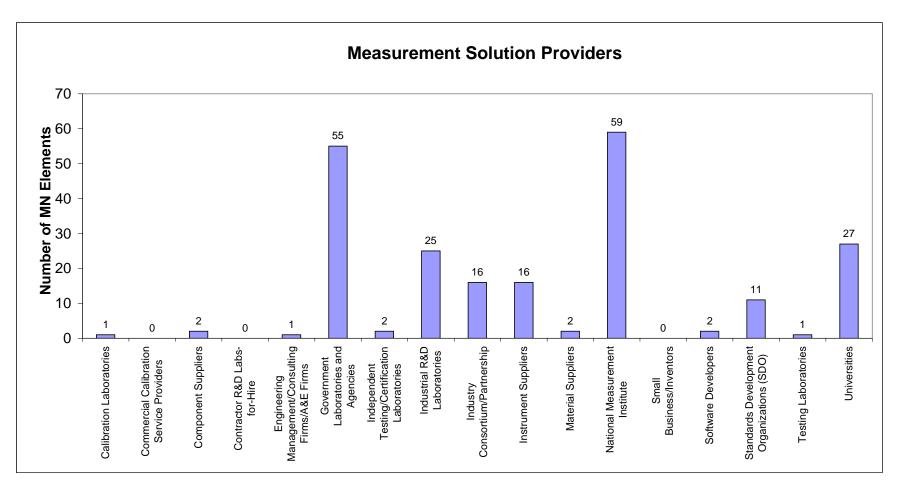


Exhibit 7.3: MN Distribution of Measurement Solutions in Healthcare

				Infrastructi	ıre										Pro	ducts							S	ervices		<u> </u>
					l	Research -												Standard/ce		Test methods or	Validated					
Co	ordinat	Data	Development -	Fund-	l	Measure-				Computati	Measure-	Measure-						rtified	Test methods for	test data for	(hardened)		Expert	Intl		
ion	/Facilit	Collection/R	Measurement	amental	l	ment	Standar	User	Calibra	onal	ment	ment	Metrics/Benc	Raw	Reference	Softw	Stability	reference	production-scale	consumer	properties	Calibrati	consulta	Recogniti	Third Party	
atio	on	etrieval	Technology	Knowledge	Protocols	Science	ds	Facility	tion	Methods	Instrument	Method	hmarks	Data	Data	are	Tests	material	measurements	products	data	on	tion	on	Verification	Total
	2	5	24	7	16	14	28	2	8	10	10	25	10	4	12	5	1	14	7	6	2	0	0	0	1	213

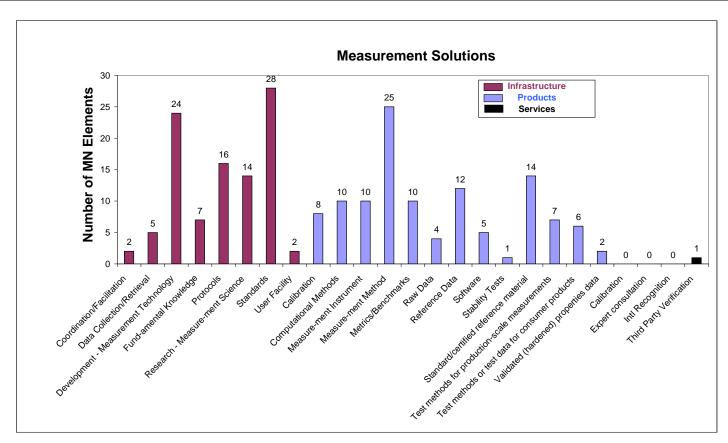


Exhibit 7.4: MN Distribution of Measurands in Healthcare

	Classical Functional													Performance			Structu	ural			
											Thermal-	Thermal-	Thermal-								
						Electronic/				Radio	Thermoch	Thermody	Thermoph	Computational	Software	System					
Biolo	ogical	Chemical	Physical	Physiological	Acoustical	Electrical	Magnetic	Optical	Photonic	frequency	emical	namic	ysical	Performance	Performance	Performance	Kinetic	Mechanical	Molecular	Spatial	Total
2	23	9	8	4	0	3	6	5	3	1	0	2	1	1	4	4	0	2	1	0	77

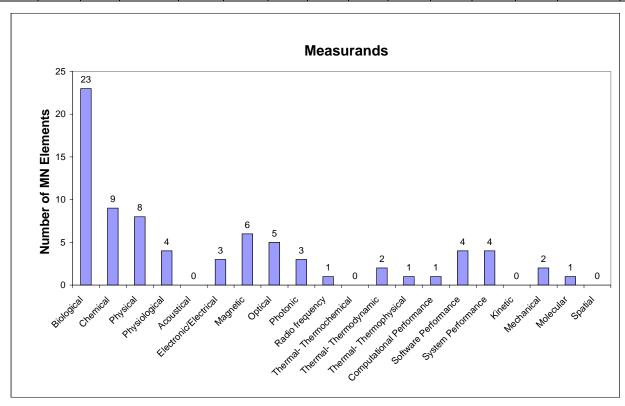


Exhibit 7.5: MN Distribution of Current Public/Private R&D Efforts in Healthcare

1	Only Public Efforts Exist	Both Public and Private Efforts Exist	No Efforts Exist
3	1	1 24	39

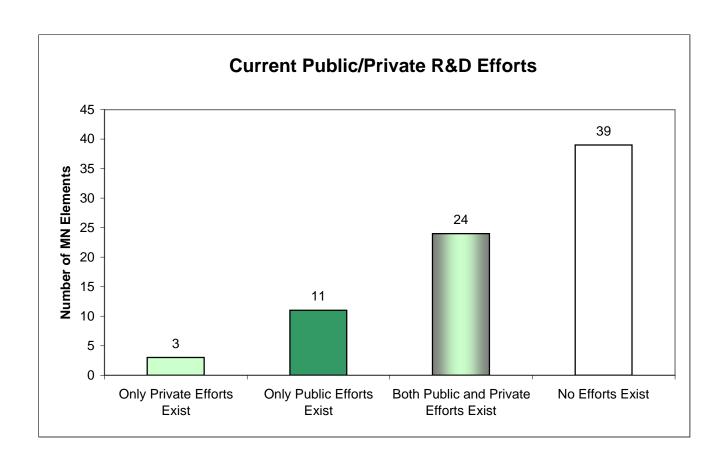


Exhibit 7.6: MN Distribution of TI as Measurement Technology in Healthcare

	Technology Innovation is not a Measurement Innovation
47	30

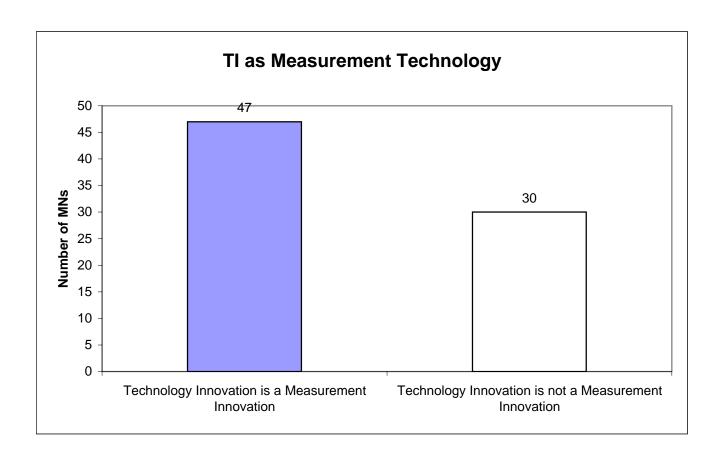


Exhibit 7.7: MN Distribution by Stage of Technological Innovation in Healthcare

Applied Research	Production	Market	End-use	Total
52	6	16	3	77

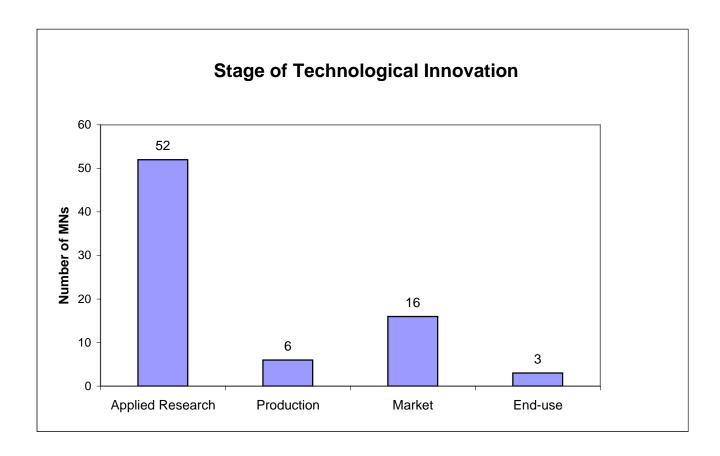


Exhibit 7.8: MN Distribution of Regulation as Driver/Barrier in Healthcare

MN Driver	MN Barrier	No Impact
20	4	53

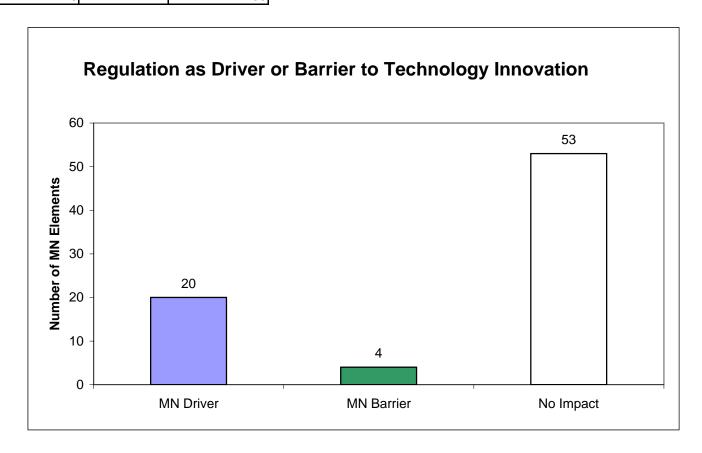


Exhibit 7.9: MN Correlation Matrix for Solution Providers and Measurement Barriers in Healthcare

					Ме	asuı	eme	nt S	olut	ion l	Barrie	ers				
Solution Providers	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Calibration laboratories			1							_	1					
Commercial calibration service providers																
Component suppliers	1								1							
Contractor R&D labs-for-hire																
Engineering management/consulting firms/A&E firms									1							
Government laboratories and agencies	3		37	13	1	3	20	3	14		13	11		3	2	1
Independent testing/certification laboratories	1		1	1					1							
Industrial R&D laboratories	1		18			1	9	3	5	1	6	8		2		
Industry consortium/partnership	3		10	7		4	5		9		6			1	1	
Instrument suppliers	1		13	5		2	6		7	1	5	3			1	
Material suppliers			1	1			1		2		1					
National Measurement Institute	3	1	36	17	1	3	21	2	21	1	20	9		3	3	1
Small business/inventors																
Software developers	1	1	1	2			1									
Standards development organizations (SDOs)	1		4	7	1	1	4		3		3	2		1	1	
Testing laboratories				1					1		1					
Universities		1	18	10		3	13	4	3		7	5		2		1

Exhibit 7.10: MN Correlation Matrix for Measurement Barriers and Measurement Solutions in Healthcare

									М	eas	ure	me	nt S	Solu	utio	ns									
			Inf	rastru	ıctu	ire								F	Pro	duc	ts					S	erv	ice	s
Measurement Solution Barriers	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Acceptability/Compatibility		1			2		2		1			1			2	2	•	1	1	1					`
Accessibility		1								1					1										
Accuracy	1	4	18	3	9	11	18	2	7	7	8	14	6	4	6	3	1	9	5	1	2				
Data, Data Collection/and or																									
Retrieval	1	4	7	1	4	2	10	2	2	5	2	7	2	1	5	1		5	1	4	1				1
Destructive							1					1						1							
Expense		1	3			3	3				1	1				1		1	2		1				
Lack of Fundamental																									
Knowledge		2		7	2	7	6		2	5	4		_	2	4	2	1	6	2	1					
Multiple Solutions Exist			2	1				1	2		1	2	1	1	1										
Not Standardized			4	1	7	2	13		2	2	3	6	3		5	4		5	1	6	1				1
Production Readiness			1			1					1														
Reliability			5	2		4	12		2		2	9	5	2	4		1	5	2	2	1				1
Resolution	1	2	11	1	2	3	2	1	3	3	3	3	1	1				1							
Small Market Demand																									
Speed			1			1	3		1		2	2			1			1							
System-Level Problem	1		1		2		1					1	2							1					
Workforce			1	1								1													

Exhibit 7.11: MN Correlation Matrix for Measurement Providers and Measurement Solutions in Healthcare

									Mea	sur	eme	nt S	olu	tions	3									
		Infr	astru	ıctu	re								Pro	oduc	ts						5	Serv	ices	
ordination/ facilitation	ta Collection/ Retrieval	velopment for Measurement Technology	ndamental Scientific Knowledge	otocols	search for Measurement Science	ındards	er Facility	libration Method	mputation Method	asurement Instrument	asurement Method	trics/ Benchmarks	w Properties Data	ference Data	ftware	ıbility Tests	ındard/CRM	st Methods - Production Scale	st Methods - Consumer Products	lidated Data	libration Services	pert Consultation	ernational Recognition	3rd Party Verification
င	Da	De	Fu	Pro	Re	Sta	Us	Ca	ပိ	Me	Ме	Me	Ra	Re	So	Sta	Sta	Te	Te	Va	Ca	Ex	Int	3rc
						1		1			1													
				2										1	1			1						
				1													1		1					
2	3	15	6	15	9	19	2	3	8	6	19	8	3	8	5	1	9	5	3	1				
						1					2			1					1					
	2	12	2	5	4	6	2	3	2	6	7	5	2	2			1	2	1					
	1	2	1	3	2	7		2	2	3	5	2		2	4		3	3	3	2				
	1	8	3	2	6	5		2	2	3	2		1	3		1	4	2	1	1				
		1			1	1					1						2							
2	2	18	4	13	9	20		8	9	9	20	9	2	10	5	1	12	3	6	1				1
																							İ	
	2					1			1					1			1							
1	3	1		3		9	1		1		2	2					3	2	2					1
						1											1							1
	1	11	5	1	8	9	1	4	4	3	12	3	2	6			2	2		1			İ	
	2	2 3 1 1 1 2 2 2 1 3 3 1 3 3 1 3 3 1 3 3 1 3 3 1 3 3 1	Coordination/ facilitation Data Collection/ Retrieval Data Collection/ Retrieval Data Collection/ Retrieval Development for Measurement Technology	Coordination/ facilitation Coordination/ facilitation Coordination/ facilitation Data Collection/ Retrieval Data Collection/ Retrieval Data Collection/ Retrieval E	Coordination/ facilitation Coordination/ facilitation Coordination/ facilitation Data Collection/ Retrieval Data Collection/ Retrieval Toole	2 3 15 6 15 9 2 12 2 5 4 1 2 1 3 2 1 8 3 2 6 1 1 1 2 2 18 4 13 9 2 1 3 1 3	Coordination/ facilitation Coordination/ facilitation Coordination/ facilitation Data Collection/ Retrieval Data Collection/ Retrieval Data Collection/ Retrieval Coordination/ Setrieval Coordination/ Setrieval Data Collection/ Retrieval Coordination/ Setrieval ordination/ facilitation Coordination/ facilitation Coordination/ facilitation Coordination/ facilitation Data Collection/ Retrieval Data Collection/ Retrieval Coordination/ Retrieval Coordination/ Retrieval Coordination/ Retrieval Coordination/ Resourcement Technology Coordination/ Research for Measurement Science Coordination/ Research for Measuremen	Infrastructure	Infrastructure	Infrastructure	Infrastructure	Infrastructure	Infrastructure	Infrastructure	Coordination/ facilitation	Infrastructure	Infrastructure	Infrastructure	Infrastructure	Infrastructure	Infrared Data Production Scale Production Sca	Infrastructure	Infrastructure	

Exhibit 7.12: MN Correlation Matrix for Stage of Technological Innovation and Measurement Barriers in Healthcare

					Me	easu	reme	nt S	olut	ion l	Barrie	ers				
Stage of Technological Innovation	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	pəədS	System-Level Problem	Workforce
Applied Research	1	1	37	16	1	4	25	4	9	1	10	13		3		1
Production	2		1	3					4		2			1	1	
Market	2		10	4		2	1		7		11				2	
End-use		·	2				1	·	3	Ť		·	·		·	

Exhibit 7.13: MN Correlation Matrix for Stage of Technological Innovation and Measurement Solutions in Healthcare

									M	eas	ure	mer	nt S	olu	tio	าร									
			Inf	rastru	ıctu	ire								P	roc	duc	ts					,	erv	ice	ŝ
Stage of Technological Innovation	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Applied Research	1	4	22	7	4	14	16	2	7	9	8	16	4	3	7		1	7	3	2	2				
Production			2		2		2				1	2			1			2	2	3					
Market	1	1			7		9		1	1		7	5	1	3	3		5	2	1					1
End-use					3		1				1		1		1	2									

Exhibit 7.14: MN Correlation Matrix for Solution Providers and Stage of Technological Innovation in Healthcare

	_	Stage of Technological Innovation						
Measurement Solution Providers	Applied Research	Production	Market	End-use				
Calibration laboratories	1							
Commercial calibration service providers								
Component suppliers		1		1				
Contractor R&D labs-for-hire								
Engineering management/consulting firms/A&E firms		1						
Government laboratories and agencies	37	4	11	3				
Independent testing/certification laboratories	1	1						
Industrial R&D laboratories	20	2	2	1				
Industry consortium/partnership	6	2	7	1				
Instrument suppliers	13	2	1					
Material suppliers	1		1					
National Measurement Institute	37	4	15	3				
Small business/inventors								
Software developers	2							
Standards development organizations (SDOs)	7		4					
Testing laboratories			1					
Universities	25	1	1					

Exhibit 7.15: MN Correlation Matrix for Stage of Technological Innovation and TI as Measurement Technology in Healthcare

Stage of Technological Innovation	TI as Measurement Technology
Applied Research	34
Production	2
Market	8
End-use	3

Exhibit 7.16: MN Correlation Matrix for TI as Measurement Technology and Measurement Barriers in Healthcare

					Me	asu	reme	nt S	olut	ion I	3arrie	ers				
Innovation Equivalency	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Technology Innovation = Measurement Innovation	3	1	33	18		3	20	3	15	1	12	11			1	·

Exhibit 7.17: MN Correlation Matrix for **Solution Providers** and **TI as Measurement Technology** in Healthcare

Measurement Solution Providers	Technology Innovation = Measurement Innovation
Calibration laboratories	1
Commercial calibration service providers	
Component suppliers	1
Contractor R&D labs-for-hire	
Engineering management/consulting firms/A&E firms	
Government laboratories and agencies	32
Independent testing/certification laboratories	1
Industrial R&D laboratories	12
Industry consortium/partnership	10
Instrument suppliers	14
Material suppliers	2
National Measurement Institute	35
Small business/inventors	
Software developers	2
Standards development organizations (SDOs)	6
Testing laboratories	1
Universities	19

Exhibit 7.18: MN Correlation Matrix for **TI as Measurement Technology** and **Measurement Solutions** in Healthcare

										M	eası	ıren	nent	Sol	lutio	ns									
			Infr	astr	uctu	ıre								Р	rodu	ıcts							Serv	ices	;
Innovation Equivalency	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Technology Innovation = Measurement		4	16	5	7	11	19	2	6	8	6	10	4	4	7	5	1	11	5	2	2				1
Innovation	L	4	10	3	- /	- 11	19		O	0	O	10	4	4	/	3	ı	11	5						

Exhibit 7.19: MN Correlation Matrix for **Regulation as Driver/Barrier** and **Measurement Solutions** in Healthcare

										Me	asu	irem	ent	Sol	utio	าร									
			Infra	stru	ıctu	re								Pro	oduc	cts							Ser	vice	S
Regulatory Issues	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Regulation is a Driver		1	4		5	3	_		1	3	2	4	3		2	4		5		1	2				
Regulation is a Barrier							4			1	1	2			1			2							1

Exhibit 7.20: MN Correlation Matrix for **Solution Providers** and **Regulation as Driver/Barrier** in Healthcare

Measurement Solution Providers	Regulation is a Driver	Regulation is a Barrier
Calibration laboratories		
Commercial calibration service providers		
Component suppliers		
Contractor R&D labs-for-hire		
Engineering management/consulting firms/A&E firms		
Government laboratories and agencies	17	2
Independent testing/certification laboratories	1	
Industrial R&D laboratories	5	1
Industry consortium/partnership	8	1
Instrument suppliers	2	1
Material suppliers		1
National Measurement Institute	16	4
Small business/inventors		
Software developers		
Standards development organizations (SDOs)	2	1
Testing laboratories		1
Universities	6	

U.S. Measurement System

Measurement Need (MN) Data Book

Chapter 8. Manufacturing (Discrete) and Automotive

Prepared by
Energetics Incorporated
for the
National Institute of Standards and Technology

April 2006

Reference List of MN Distribution Charts and MN Correlation Matrices

Distributi	ion Charts	Page
Exhibit Nu	umber	_
8.1	Measurement Barriers (Manufacturing (Discrete) and Automotive)	1
8.2	Solution Providers (Manufacturing (Discrete) and Automotive)	2
8.3	Measurement Solutions (Manufacturing (Discrete) and Automotive)	3
8.4	Measuranos uvianulaciunno i Discrete) and Automotive)	4
8.5	Current Public/Private R&D Efforts (Manufacturing (Discrete) and Automotive)	5
8.6	IT as Measurement Technology (Manufacturing (Discrete) and Automotive)	6
8.7	Stage of Technological Innovation (Manufacturing (Discrete) and Automotive)	7
8.8	Regulation as Driver/Barrier (Manufacturing (Discrete) and Automotive)	8
	ion Matrices	
Exhibit No		•
8.9	Solution Providers – Measurement Barriers (Manufacturing (Discrete) and Automotive)	9
8.10	Measurement Barriers – Measurement Solutions (Manufacturing (Discrete) and Automotive)	10
8.11	Solution Providers – Measurement Solutions (Manufacturing (Discrete) and Automotive)	11
8.12	Stage of Technological Innovation – Measurement Barriers (Manufacturing (Discrete) and Automotive)	12
8.13	Stage of Technological Innovation – Measurement Solutions (Manufacturing (Discrete) and Automotive)	13
8.14	Solution Providers – Stage of Technological Innovation (Manufacturing (Discrete) and Automotive)	14
8.15	Stage of Technological Innovation – TI as Measurement Technology (Manufacturing (Discrete) and Automotive)	15 16
8.16	TI as Measurement Technology – Measurement Barriers (Manufacturing (Discrete) and Automotive)	16 17
8.17	Solution Providers – TI as Measurement Technology (Manufacturing (Discrete) and Automotive)	
8.18	TI as Measurement Technology – Measurement Solutions (Manufacturing (Discrete) and Automotive)	18
8.19	Regulation as Driver/Barrier – Measurement Solutions (Manufacturing (Discrete) and Automotive)	19
8.20	Solution Providers - Regulation as Driver/Barrier (Manufacturing (Discrete) and Automotive)	20

Exhibit 8.1: MN Distribution of Measurement Barriers in Manufacturing (Discrete) and Automotive

ſ																	
				Data, Data			Lack of		Not				Small		Syste		1
				Collection			Fundamental	Multiple	Standardi	Production	Reliabil	Resolut	market		ms-	Workforc	1
	Acceptibility	Accessibility	Accuracy	& Retrieval	Destructive	Expense	Knowledge	Solutions	zed	Readiness	ity	ion	demand	Speed	level	е	Total
Ī	3	2	17	18	4	3	3	2	8	0	11	8	0	5	1	0	85

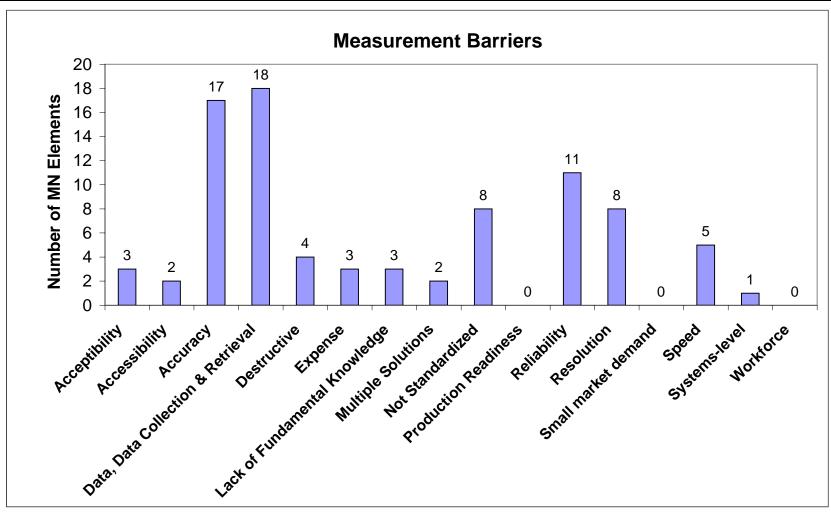


Exhibit 8.2: MN Distribution of Measurement Solution Providers in Manufacturing (Discrete) and Automotive

				Engineering													
	Commercial			Management/C		Independent								Standards			
	Calibration		Contractor	onsulting	Government	Testing/Certifica		Industry			National	Small		Development			
Calibration	Service	Component	R&D Labs-for-	Firms/A&E	Laboratories	tion	Industrial R&D	Consortium/	Instrument	Material	Measurement	Business/I	Software	Organizations	Testing		
Laboratories	Providers	Suppliers	Hire	Firms	and Agencies	Laboratories	Laboratories	Partnership	Suppliers	Suppliers	Institute	nventors	Developers	(SDO)	Laboratories	Universities	Total
1	0	3	0	1	11	1	9	8	8	2	24	0	2	4	0	9	83

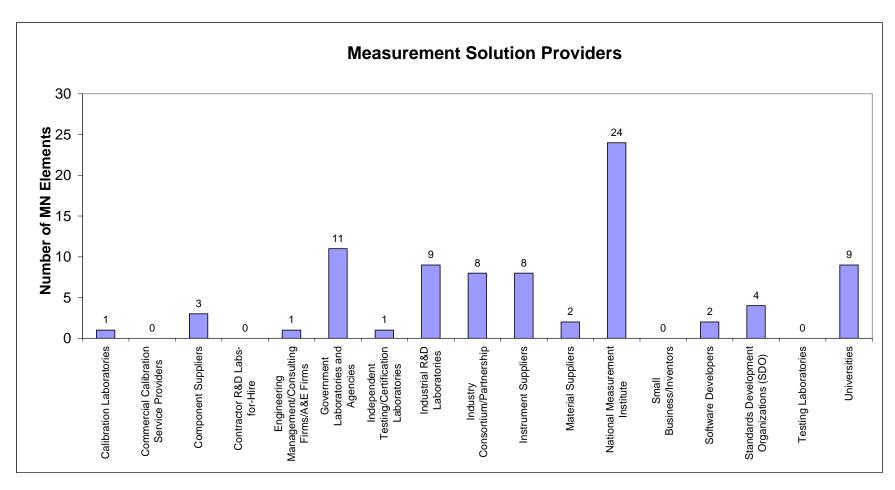


Exhibit 8.3: MN Distribution of Measurement Solutions in Manufacturing (Discrete) and Automotive

				Infrastructi	ure										Proc	ducts							S	ervices		1
						Research -				l								Standard/ce		Test methods or	Validated					
Coo	rdinat	Data	Development -	Fund-		Measure-				Computati	Measure-	Measure-						rtified	Test methods for	test data for	(hardened)		Expert	Intl		
ion/f	Facilit	Collection/R	Measurement	amental		ment	Standar	User	Calibra	onal	ment	ment	Metrics/Benc	Raw	Reference	Softw	Stability	reference	production-scale	consumer	properties	Calibrati	consulta	Recogniti	Third Party	
ation	n	etrieval	Technology	Knowledge	Protocols	Science	ds	Facility	tion	Methods	Instrument	Method	hmarks	Data	Data	are	Tests	material	measurements	products	data	on	tion	on	Verification	Total
	4	5	9	2	0	2	10	2	5	8	10	8	2	1	2	1	0	3	6	2	2	0	1	0	4	89

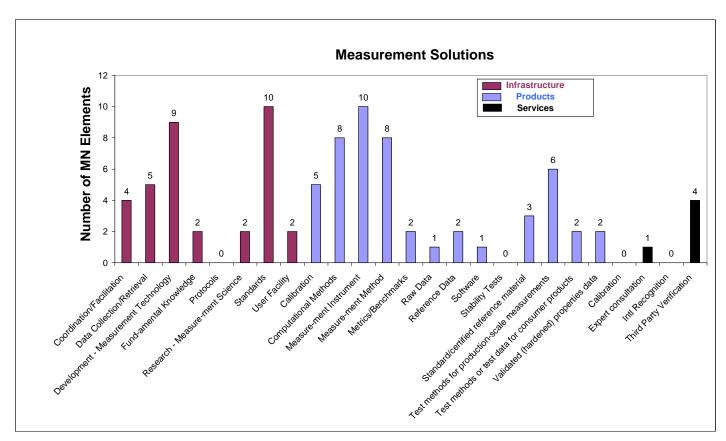


Exhibit 8.4: MN Distribution of Measurands in Manufacturing (Discrete) and Automotive

	Cla	ssical						Functiona	l					Performance			Structu	ıral		<u> </u>
										Thermal-	Thermal-	Thermal-								
					Electronic/				Radio	Thermoch	Thermody	Thermoph	Computational	Software	System				, ,	1
Biological	Chemical	Physical	Physiological	Acoustical	Electrical	Magnetic	Optical	Photonic	frequency	emical	namic	ysical	Performance	Performance	Performance	Kinetic	Mechanical	Molecular	Spatial	Total
0	0	12	1	0	1	0	1	0	1	1	1	2	1	1	2	1	4	0	3	32

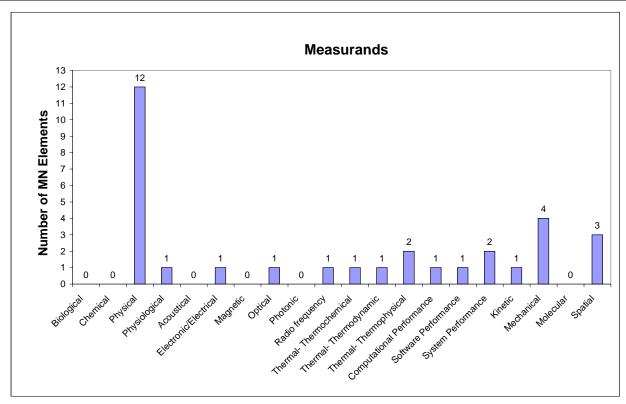


Exhibit 8.5: MN Distribution of Current Public/Private R&D Efforts in Manufacturing (Discrete) and Automotive

Only Private		Only Public	Both Public and	
Efforts Exist		Efforts Exist	Private Efforts Exist	No Efforts Exist
	3	6	2	21

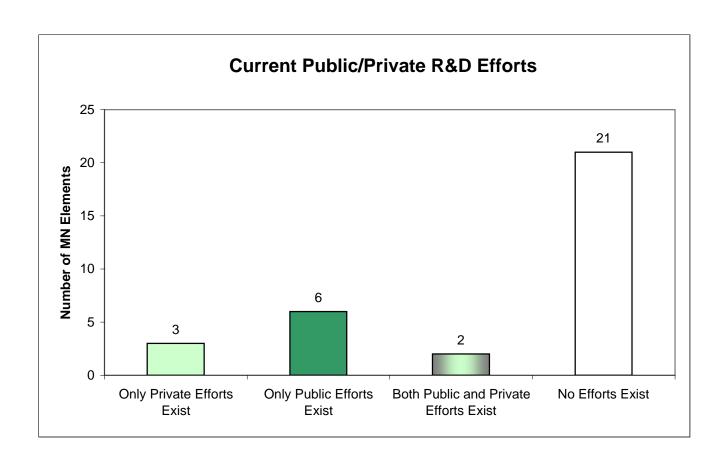


Exhibit 8.6: MN Distribution of TI as Measurement Technology in Manufacturing (Discrete) and Automotive

Technology Innovation	
	Technology Innovation is not a
Innovation	Measurement Innovation
20	12

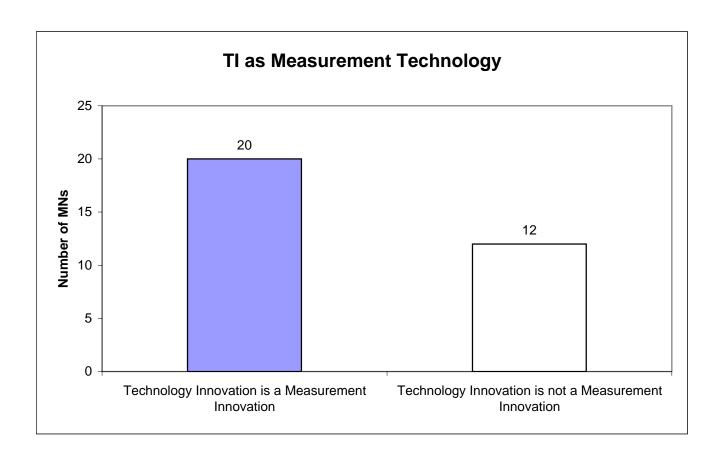


Exhibit 8.7: MN Distribution by Stage of Technological Innovation in Manufacturing (Discrete) and Automotive

Applied Research	Production	Market	End-use	Total
23	7	1	1	32

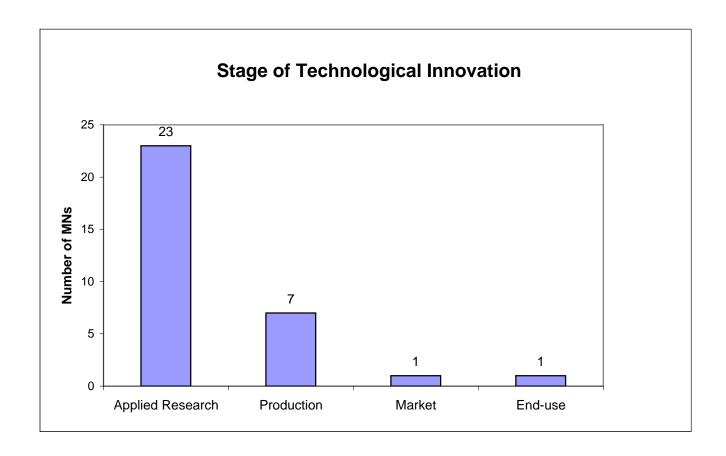


Exhibit 8.8: MN Distribution of Regulation as Driver/Barrier in Manufacturing (Discrete) and Automotive

MN Driver	MN Barrier	No Impact	
2	3		27

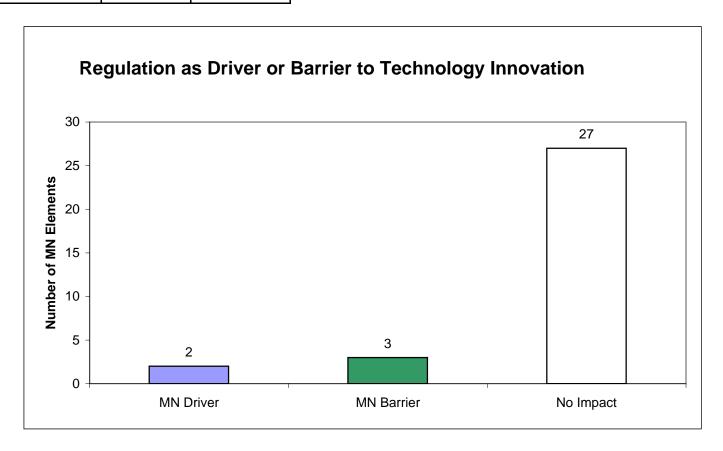


Exhibit 8.9: MN Correlation Matrix for Solution Providers and Measurement Barriers in Manufacturing (Discrete) and Automotive

					Ме	asuı	reme	nt S	olut	ion l	Barrie	ers				
Solution Providers	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Calibration laboratories			1	1					1					- 11		
Commercial calibration service providers																
Component suppliers			2	1		1		1	1		3					
Contractor R&D labs-for-hire																
Engineering management/consulting firms/A&E firms				1							1				1	
Government laboratories and agencies	1	1	5	5	2	1	2		1		3	4		4		
Independent testing/certification laboratories				1					1		1					
Industrial R&D laboratories	2		5				2	1	2		2	4		1		
Industry consortium/partnership		1	5	5	1	1		1	2		3	2				
Instrument suppliers		1	6	4	1	1	1	1	1		3	2		1		
Material suppliers			1	2				1	1							
National Measurement Institute	2	2	14	13	3	2	2	1	6		8	6		4	1	
Small business/inventors																
Software developers	1			1					1		1					
Standards development organizations (SDOs)	1		2	2		1			1		2	1				
Testing laboratories																
Universities	1	1	4	6	1	1	1		1		2	2		3		

Exhibit 8.10: MN Correlation Matrix for Measurement Barriers and Measurement Solutions in Manufacturing (Discrete) and Automotive

									M	eas	ure	me	nt S	Solu	ıtio	ns										
			Inf	rastru	ıctı	ire								F	Pro	duc	ts						S	erv	rice	s
Measurement Solution Barriers	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer	Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Acceptability/Compatibility	1						2				1								1		1				_	
Accessibility			1					1	2			1							1							
Accuracy		2	7			2	5	2	5	2	5	4	1	1	1			3		1	1			1		2
Data, Data Collection/and or																										
Retrieval	3	5	2	1		1	7	1	1	6	5	3	2	1	2	1			4	1	2	2				3
Destructive	1		1						1	2	2	3						1				1				
Expense		1							2	1	2							1								1
Lack of Fundamental																										
Knowledge	1			1							3	2									1					
Multiple Solutions Exist			2			2	1				1															
Not Standardized	1	1					5	1		2	1		2	1	1			1	3	3		1				1
Production Readiness																										
Reliability	1	2	4	1		1	2		3	2	2	1			1	1		2	2	2	1	1				4
Resolution			3	1			2	1	1	1	4	6						1	1					1		
Small Market Demand																										
Speed	1	1	3	1						3	3	2														
System-Level Problem	1	1														1										
Workforce																									Ť	

Exhibit 8.11: MN Correlation Matrix for Measurement Providers and Measurement Solutions in Manufacturing (Discrete) and Automotive

										Mea	sur	eme	ent S	olut	tions	3									
			Infra	astru	ıctu	e								Pro	oduc	ts							Serv	ices	
	Coordination/ facilitation	ta Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Measurement Solution Providers	၀၁	Data	De	Fu	Pro	Re	Sta	ΝS	Ca	ပိ	Me	Me	Me	Ra	Re	So	Sta	Sta	Te	Ë	Va	Ca	Ĕ	Ĭ	310
Calibration laboratories							1							1					1						
Commercial calibration service providers																									
Component suppliers			1			1	1		1		2								1						1
Contractor R&D labs-for-hire																									
Engineering management/consulting																									
firms/A&E firms	1	1														1									
Government laboratories and agencies	1	1	3	1			2	1	2	3	6	5	1							2					1
Independent testing/certification laboratories							1												1						1
Industrial R&D laboratories	1	1	3			1	2			1	5	3						1	2	2			1		1
Industry consortium/partnership		1	1			1	4	1	2	3	1	3							2		2				1
Instrument suppliers	1	1	4	1		1	3		2	2	1	2		1				2	2						1
Material suppliers			1			1	2			1			1												
National Measurement Institute	4	5	8	2		1	5	2	4	6	7	6	1	1	1	1		3	5	1	2		1		2
Small business/inventors																									
Software developers	1						2								1										1
Standards development organizations (SDOs)							3			1		1			1			1	1						2
Testing laboratories						j																			\neg
Universities		1	3				3		2	4	5	2	1		1				2	1					1

Exhibit 8.12: MN Correlation Matrix for Stage of Technological Innovation and Measurement Barriers in Manufacturing (Discrete) and Automotive

					Me	easu	reme	ent S	olu	ion	Barrie	ers				
Stage of Technological	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	peeds	System-Level Problem	Workforce
	4	2	14		3		3	2	5	_	8		()	<u></u>	(C)	
Applied Research					_		3	1				•		4		
Production	1		3	5	1	1		1	1		3	1		1	1	
Market				1					1							
End-use	1								1							

Exhibit 8.13: MN Correlation Matrix for Stage of Technological Innovation and Measurement Solutions in Manufacturing (Discrete) and Automotive

									M	eas	ure	mei	nt S	olu	tior	าร										
			Inf	rastru	ctu	re								Р	roc	luc	ts						S	erv	ices	3
Stage of Technological Innovation	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	est N	Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Applied Research	1	3	8	2		1	5	2	5	4	10	6	1	1	2			2	5		2	1		1		3
Production	2	2	1			1	3			3		2				1		1	1			1				1
Market							1			1			1													
End-use	1						1																			

Exhibit 8.14: MN Correlation Matrix for Solution Providers and Stage of Technological Innovation in Manufacturing (Discrete) and Automotive

	Stage (of Tech tion	nologi	cal
Measurement Solution Providers	Applied Research	Production	Market	End-use
Calibration laboratories	1			
Commercial calibration service providers	-			
Component suppliers	3			
Contractor R&D labs-for-hire				
Engineering management/consulting firms/A&E firms		1		
Government laboratories and agencies	9	1	1	
Independent testing/certification laboratories	1			
Industrial R&D laboratories	8	1		
Industry consortium/partnership	5	3		
Instrument suppliers	5	3		
Material suppliers		1	1	
National Measurement Institute	18	5		1
Small business/inventors				
Software developers	1			1
Standards development organizations (SDOs)	1	3		
Testing laboratories				
Universities	8		1	

Exhibit 8.15: MN Correlation Matrix for Stage of Technological Innovation and TI as Measurement Technology in Manufacturing (Discrete) and Automotive

Stage of Technological Innovation	TI as Measurement Technology
Applied Research	15
Production	4
Market	
End-use	1

Exhibit 8.16: MN Correlation Matrix for TI as Measurement Technology and Measurement Barriers in Manufacturing (Discrete) and Automotive

					Ме	asu	reme	nt S	olut	ion l	3arrie	ers				
Innovation Equivalency	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	peed	System-Level Problem	Workforce
Technology Innovation = Measurement Innovation	2	2	13	10	1	2	1	1	5		6	6		3	1	

Exhibit 8.17: MN Correlation Matrix for Solution Providers and TI as Measurement Technology in Manufacturing (Discrete) and Automotive

Measurement Solution Providers	Technology Innovation = Measurement Innovation
Calibration laboratories	1
Commercial calibration service providers	
Component suppliers	2
Contractor R&D labs-for-hire	
Engineering management/consulting firms/A&E firms	1
Government laboratories and agencies	6
Independent testing/certification laboratories	
Industrial R&D laboratories	5
Industry consortium/partnership	4
Instrument suppliers	6
Material suppliers	
National Measurement Institute	18
Small business/inventors	
Software developers	1
Standards development organizations (SDOs)	2
Testing laboratories	
Universities	4

Exhibit 8.18: MN Correlation Matrix for TI as Measurement Technology and Measurement Solutions in Manufacturing (Discrete) and Automotive

										M	eası	ıren	nent	Sol	lutio	ns									
			Infr	astr	uctu	ıre								Р	rodu	ıcts							Serv	ices	;
Innovation Equivalency	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Technology Innovation = Measurement	3	5	7	1		1	5	2	5	3	6	5	1	1	1	1		1	4	1	1		1		1
Innovation	3	5	- /	- 1		ı,	5	2	3	3	О	5	- 1	- 1	ı	ı		ı	4		'				- 1

Exhibit 8.19: MN Correlation Matrix for Regulation as Driver/Barrier and Measurement Solutions in Manufacturing (Discrete) and Automotive

										N	leas	urer	nen	t So	lutio	ons									
			Infr	astı	ructi	ure								Pro	oduc	cts							Ser	vice	S
Regulatory Issues	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Regulation is a Driver	1	1					1									1			1						
Regulation is a Barrier		1					2			1			1	1					1	1					1

Exhibit 8.20: MN Correlation Matrix for Solution Providers and Regulation as Driver/Barrier in Manufacturing (Discrete) and Automotive

Measurement Solution Providers	Regulation is a Driver	Regulation is a Barrier
Calibration laboratories		1
Commercial calibration service providers		
Component suppliers		
Contractor R&D labs-for-hire		
Engineering management/consulting firms/A&E firms	1	
Government laboratories and agencies		2
Independent testing/certification laboratories		
Industrial R&D laboratories	1	1
Industry consortium/partnership		
Instrument suppliers		1
Material suppliers		1
National Measurement Institute	2	2
Small business/inventors		
Software developers		
Standards development organizations (SDOs)	1	
Testing laboratories		
Universities		1

U.S. Measurement System

Measurement Need (MN) Data Book

Chapter 9. Materials

(includes Ceramics, Metals, and Polymers)

Prepared by
Energetics Incorporated
for the
National Institute of Standards and Technology

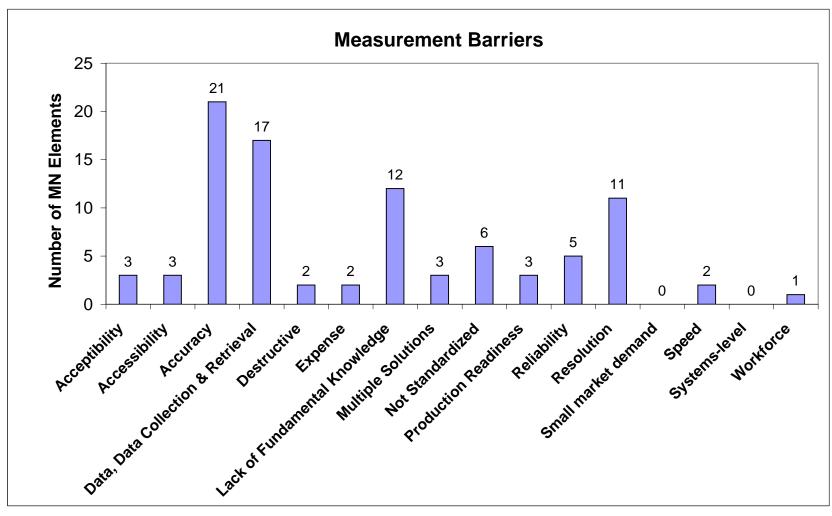
April 2006

Reference List of MN Distribution Charts and MN Correlation Matrices

Distribut	tion Charts	Page
Exhibit No	Number	_
9.1	Measurement Barriers (Materials)	1
9.2	Solution Providers (Materials)	2
9.3	Measurement Solutions (Materials) Measurands (Materials)	3
9.4		
9.5	Current Public/Private R&D Efforts (Materials)	5
9.6	11 as Measurement reciniology (Materiais)	· · · · · · · · · · · · · · · · · · ·
9.7	Stage of Technological Innovation (Materials)	7
9.8	Regulation as Driver/Barrier (Materials)	8
Correlation Exhibit No.	tion Matrices Number	
9.9	Solution Providers – Measurement Barriers (Materials)	9
9.10		10
9.11		
9.12		12
9.13	Stage of Technological Innovation – Measurement Solutions (Materials)	13
9.14	Solution Providers – Stage of Technological Innovation (Materials)	14
9.15		15
9.16	TI as Measurement Technology – Measurement Barriers (Materials)	16
9.17	Solution Providers – TI as Measurement Technology (Materials)	17
9.18	11 as Measurement Technology – Measurement Solutions (Materials)	18
9.19	Regulation as Driver/Barrier – Measurement Solutions (Materials)	19
9.20	Solution Providers – Regulation as Driver/Barrier (Materials)	20

Exhibit 9.1: MN Distribution of Measurement Barriers in Materials

			Data, Data			Lack of		Not				Small		Syste		l
			Collection			Fundamental	Multiple	Standardi	Production	Reliabil	Resolut	market		ms-	Workforc	1
Acceptibility	Accessibility	Accuracy	& Retrieval	Destructive	Expense	Knowledge	Solutions	zed	Readiness	ity	ion	demand	Speed	level	е	Total
3	3	21	17	2	2	12	3	6	3	5	11	0	2	0	1	91



1

Exhibit 9.2: MN Distribution of Measurement Solution Providers in Materials

				Engineering													
	Commercial			Management/C		Independent								Standards			
	Calibration		Contractor	onsulting	Government	Testing/Certifica		Industry			National	Small		Development			
Calibration	Service	Component	R&D Labs-for-	Firms/A&E	Laboratories	tion	Industrial R&D	Consortium/	Instrument	Material	Measurement	Business/I	Software	Organizations	Testing		
Laboratories	Providers	Suppliers	Hire	Firms	and Agencies	Laboratories	Laboratories	Partnership	Suppliers	Suppliers	Institute	nventors	Developers	(SDO)	Laboratories	Universities	Total
0	0	1	0	0	27	2	8	9	9	6	25	0	0	10	0	16	113

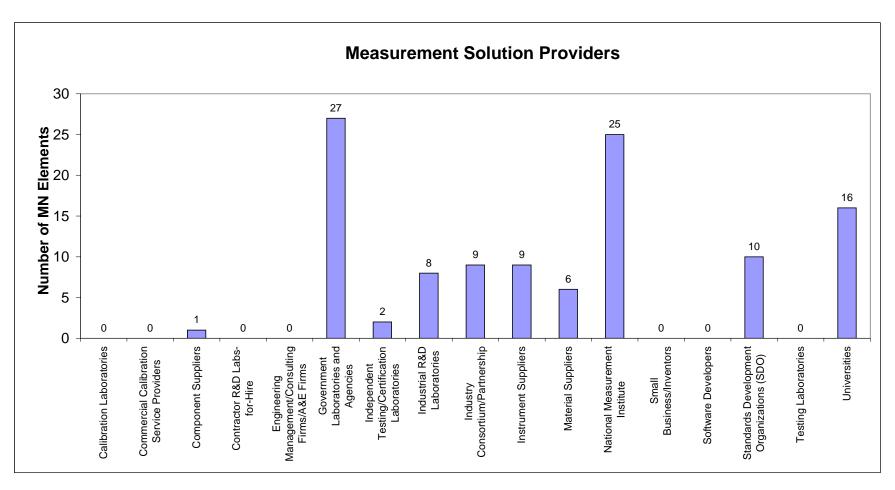


Exhibit 9.3: MN Distribution of Measurement Solutions in Materials

			Infrastruct	ure					Produc						ducts							S	ervices		1
					Research -												Standard/ce		Test methods or	Validated					
Coordi	nat Data	Development -	Fund-		Measure-				Computati	Measure-	Measure-						rtified	Test methods for	test data for	(hardened)		Expert	Intl		
ion/Fac	ilit Collection/R	Measurement	amental		ment	Standar	User	Calibra	onal	ment	ment	Metrics/Benc	Raw	Reference	Softw	Stability	reference	production-scale	consumer	properties	Calibrat	consulta	Recogniti	Third Party	
ation	etrieval	Technology	Knowledge	Protocols	Science	ds	Facility	tion	Methods	Instrument	Method	hmarks	Data	Data	are	Tests	material	measurements	products	data	on	tion	on	Verification	Total
2	1	16	6	4	8	10	3	1	9	2	16	2	5	3	0	0	4	2	0	1	0	0	2	2	99

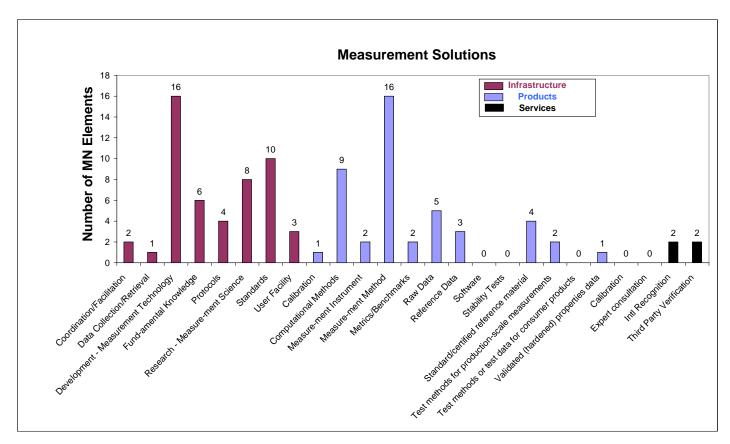


Exhibit 9.4: MN Distribution of Measurands in Materials

		Cla	ssical						Functional						Performance			Structi	ural		<u> </u>
											Thermal-	Thermal-	Thermal-								
						Electronic/				Radio	Thermoch	Thermody	Thermoph	Computational	Software	System					
Bi	ological	Chemical	Physical	Physiological	Acoustical	Electrical	Magnetic	Optical	Photonic	frequency	emical	namic	ysical	Performance	Performance	Performance	Kinetic	Mechanical	Molecular	Spatial	Total
	0	8	8	1	0	4	3	0	1	1	0	2	2	0	0	1	0	5	4	0	40

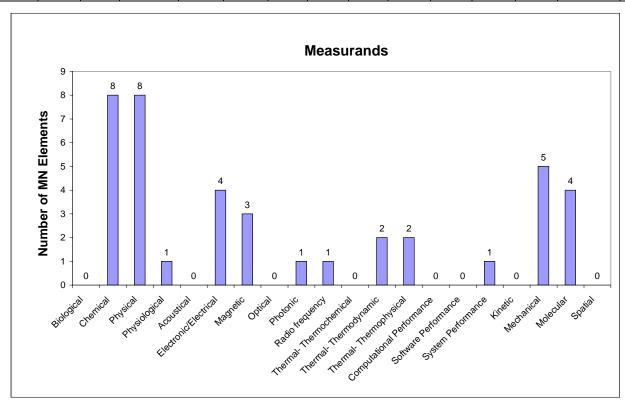


Exhibit 9.5: MN Distribution of Current Public/Private R&D Efforts in Materials

	•	Both Public and Private Efforts Exist	No Efforts Exist
6	5	14	15

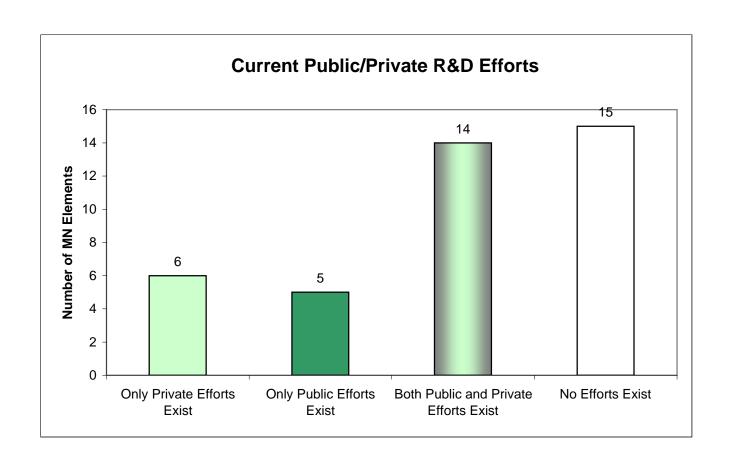


Exhibit 9.6: MN Distribution of TI as Measurement Technology in Materials

	Technology Innovation is not a Measurement Innovation
IIIIIOvation	IMEASULEINENL IIIIOVALION
10	30

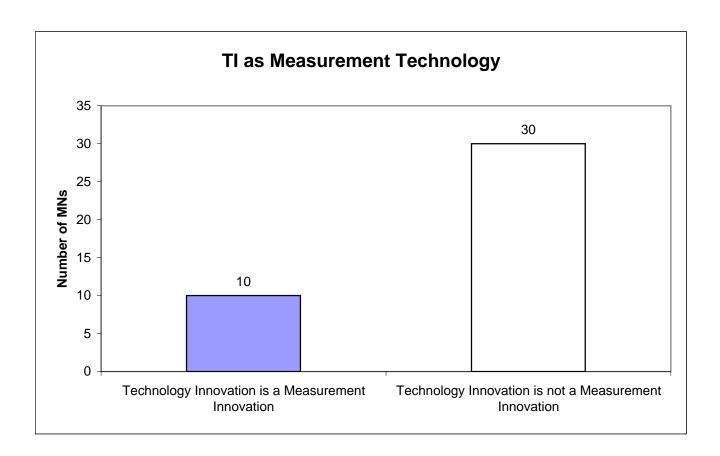


Exhibit 9.7: MN Distribution by Stage of Technological Innovation in Materials

Applied Research	Production	Market	End-use	Total
28	9	3	0	40

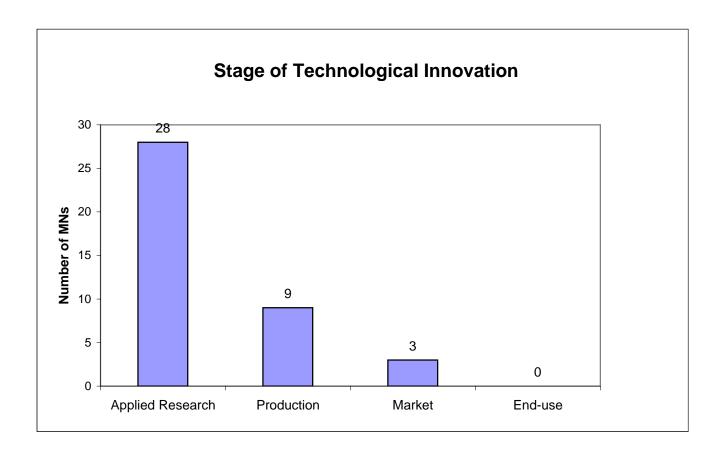


Exhibit 9.8: MN Distribution of Regulation as Driver/Barrier in Materials

MN Driver	MN Barrier	No Impact	
4	1		35

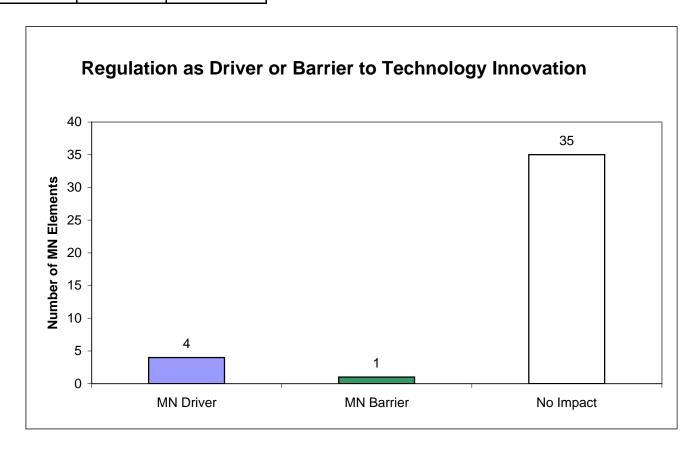


Exhibit 9.9: MN Correlation Matrix for Solution Providers and Measurement Barriers in Materials

					Ме	asuı	reme	nt S	olut	ion l	Barri	ers				
Solution Providers	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Calibration laboratories	⋖	∢	⋖			Е		2	Z	_	~	~	တ	S	_	
Commercial calibration service providers															\dashv	
Component suppliers								1	1						\longrightarrow	
Contractor R&D labs-for-hire								- '	- '						\dashv	
Engineering management/consulting firms/A&E firms																
Government laboratories and agencies	1	2	14	9	1	1	11		2	3	2	10		1		1
Independent testing/certification laboratories	1		1	3	-	-			2			10		- 1	-	
Industrial R&D laboratories	1		5	2	1		4		1		1	3			\dashv	\dashv
Industry consortium/partnership		2		4		1	1	1	- 1	1	1	3		1	-+	\dashv
Instrument suppliers			6	3		•	4	1	1	1		2			-	-
Material suppliers	2	1	3	5			1	2	1	-		1		1	\dashv	\dashv
National Measurement Institute	1	2	_		2	2	6	1	4	2	5	8		2	$\overline{}$	1
Small business/inventors															$\neg \uparrow$	
Software developers															$\neg \uparrow$	\neg
Standards development organizations (SDOs)	2	1	4	3			1	2	5	1	1	1			\neg	\neg
Testing laboratories											•				\neg	\neg
Universities	1	1	7	11		1	6	1			3	4		1		1

Exhibit 9.10: MN Correlation Matrix for Measurement Barriers and Measurement Solutions in Materials

									M	eas	ure	me	nt S	Solu	ıtio	ns									
			Inf	rastru	ıctı	ıre								F	Pro	duc	ts					S	erv	ice	s
Measurement Solution Barriers	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Acceptability/Compatibility		1	1		1		1							1				1	1					2	
Accessibility	1						1		1		1	3						1							1
Accuracy	2		11	1	2	4	6	1	1	2	1	8	2	3	2			2	1						1
Data, Data Collection/and or																									
Retrieval	1	1	5		3	4	5	2	1	7	1	6	1	4	1			2	1		1			1	1
Destructive				1		1				1		2									1				
Expense			1			1	1				1	1													
Lack of Fundamental																									
Knowledge			5	6	3	4				4		3	1	1				1							
Multiple Solutions Exist		1	1			1	3					1												1	1
Not Standardized	1				1		2			1		4		1				3	1					1	1
Production Readiness			2									1			1										
Reliability			2			2				3		2		1				1			1				
Resolution	1		7			1	3	2		3	1	5	2	2	1										
Small Market Demand																									
Speed							1	1		1	1	2													
System-Level Problem																									
Workforce			1	1								1													

Exhibit 9.11: MN Correlation Matrix for Measurement Providers and Measurement Solutions in Materials

										Mea	sur	eme	ent S	olu	tions	3									
			Infr	astru	ıctu	re								Pro	oduc	ts						5	Serv	ices	
	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Measurement Solution Providers	ပ	Da	Бe	Fu	Pr	Re	St	Us	Ca	ပိ	Me	Me	Me	Ra	Re	So	Sta	Sta	Te	Te	۷a	Ca	Ĕ	Int	3.0
Calibration laboratories																									
Commercial calibration service providers																									
Component suppliers							1					1													1
Contractor R&D labs-for-hire																									
Engineering management/consulting firms/A&E firms																									
Government laboratories and agencies	2		13	6	3	5	5	2		4	2	11	2	4	3			1							
Independent testing/certification laboratories							1					1		1				1	1					1	
Industrial R&D laboratories			5	2	1	3	1			2		2	1	2	1			1							
Industry consortium/partnership			3			1	5		1	3	1	5			1				1		1				1
Instrument suppliers			7	3	2	3	2	1		1	1							1							
Material suppliers	1	1	2		1	2	2	1		2		2		2				1						1	
National Measurement Institute	1		9	3	1	4	4	3	1	7	2	13	2	2	2			3	2		1			1	2
Small business/inventors																									
Software developers																									
Standards development organizations (SDOs)	1	1	1		1		5					5		1	1			2	1					2	1
Testing laboratories																									
Universities		1	4	3	2	5	4	1	1	5		6	1	3	1			1	1					1	1

Exhibit 9.12: MN Correlation Matrix for Stage of Technological Innovation and Measurement Barriers in Materials

					Me	easu	reme	nt S	olut	ion	Barrie	ers				
Stage of Technological	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	peeds	System-Level Problem	Workforce
		٧													Ś	
Applied Research	2	1	13			2	10				4	_		2		1
Production		2	6	4	1		2	1	1	1	1	2				
Market	1		2						2			1				
End-use																

Exhibit 9.13: MN Correlation Matrix for Stage of Technological Innovation and Measurement Solutions in Materials

									M	eas	ure	mei	nt S	olu	tio	าร									
			Inf	rastru	ıctu	re								F	roc	duc	ts					9,	Serv	ices	3
Stage of Technological Innovation	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Applied Research	1	1	12	5	3	7	6	3		7	2	11	2	4	2			2	1					1	1
Production	1		3	1	1	1	2		1	2		4			1			1			1				1
Market			1				2					1		1				1	1					1	
End-use																									

Exhibit 9.14: MN Correlation Matrix for Solution Providers and Stage of Technological Innovation in Materials

	Stage of	of Tech tion	nologio	cal
Measurement Solution Providers	Applied Research	Production	Market	End-use
Calibration laboratories			_	
Commercial calibration service providers				
Component suppliers	1			
Contractor R&D labs-for-hire				
Engineering management/consulting firms/A&E firms				
Government laboratories and agencies	20	6	1	
Independent testing/certification laboratories			2	
Industrial R&D laboratories	6	1	1	
Industry consortium/partnership	3	5	1	
Instrument suppliers	5	3	1	
Material suppliers	4	2		
National Measurement Institute	22	2	1	
Small business/inventors				
Software developers				
Standards development organizations (SDOs)	4	4	2	
Testing laboratories				
Universities	13	3		

Exhibit 9.15: MN Correlation Matrix for Stage of Technological Innovation and TI as Measurement Technology in Materials

Stage of Technological Innovation	Ti as Measurement Technology
Applied Research	9
Production	1
Market	
End-use	

Exhibit 9.16: MN Correlation Matrix for TI as Measurement Technology and Measurement Barriers in Materials

					Ме	asu	reme	nt S	olut	ion I	Barrie	ers				
Innovation Equivalency	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Technology Innovation = Measurement Innovation	1		7	4			3			2		4	·	1		

Exhibit 9.17: MN Correlation Matrix for Solution Providers and TI as Measurement Technology in Materials

Measurement Solution Providers	Technology Innovation = Measurement Innovation
Calibration laboratories	. –
Commercial calibration service providers	
Component suppliers	
Contractor R&D labs-for-hire	
Engineering management/consulting firms/A&E firms	
Government laboratories and agencies	8
Independent testing/certification laboratories	
Industrial R&D laboratories	2
Industry consortium/partnership	2
Instrument suppliers	1
Material suppliers	2
National Measurement Institute	7
Small business/inventors	
Software developers	
Standards development organizations (SDOs)	2
Testing laboratories	4
Universities	4

Exhibit 9.18: MN Correlation Matrix for TI as Measurement Technology and Measurement Solutions in Materials

										Mea	asur	eme	ent S	Solu	tion	S									
			Infr	astr	uctu	ire								Pr	oduc	ts							Serv	ices	
Innovation Equivalency	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Technology Innovation = Measurement			4		0		2	4				_	0	4											
Innovation			4		2		3	1				5	2	1	1										

Exhibit 9.19: MN Correlation Matrix for Regulation as Driver/Barrier and Measurement Solutions in Materials

										Mea	sur	eme	nt S	olu	tions	S									
			Infra	stru	ıctu	re								Pro	oduc	cts						Ç	Serv	ices	;
Regulatory Issues Regulation is a Driver	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Regulation is a Barrier			- '			- 1	- '		- '			- 0		•				1	1					1	•
regulation is a Darrier																									

Exhibit 9.20: MN Correlation Matrix for Solution Providers and Regulation as Driver/Barrier in Materials

Measurement Solution Providers	Regulation is a Driver	Regulation is a Barrier
Calibration laboratories		_
Commercial calibration service providers		
Component suppliers		
Contractor R&D labs-for-hire		
Engineering management/consulting firms/A&E firms		
Government laboratories and agencies	1	
Independent testing/certification laboratories	1	1
Industrial R&D laboratories	1	
Industry consortium/partnership	1	
Instrument suppliers		
Material suppliers		
National Measurement Institute	3	1
Small business/inventors		
Software developers		
Standards development organizations (SDOs)	2	1
Testing laboratories		
Universities	2	

U.S. Measurement System

Measurement Need (MN) Data Book

Chapter 10. Nanotechnology

Prepared by
Energetics Incorporated
for the
National Institute of Standards and Technology

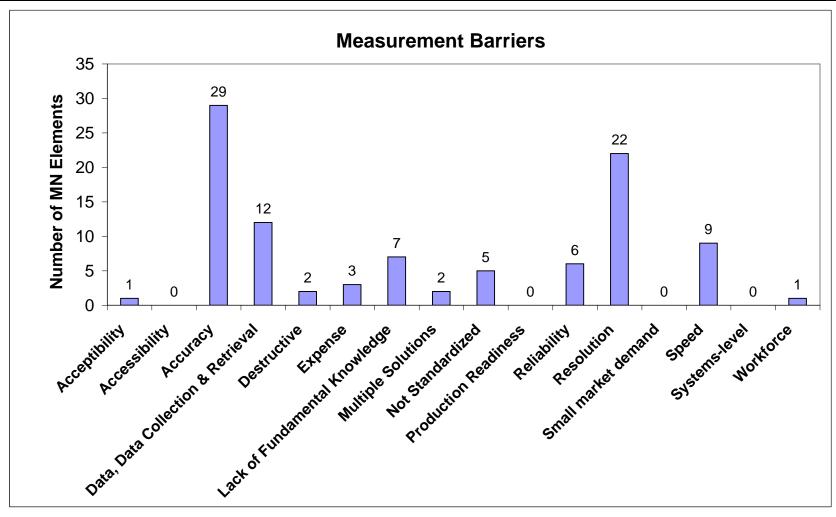
April 2006

Reference List of MN Distribution Charts and MN Correlation Matrices

Distributi	ion Charts	Page
Exhibit Nu	umber	_
10.1	Measurement Barriers (Nanotechnology)	1
10.2	Solution Providers (Nanotechnology)	2
10.3	Measurement Solutions (Nanotechnology)	3
10.4	Measurands (Nanotechnology)	4
10.5	Carrolle ability invato read Ellotto (realistocimology)	O O
10.6		
10.7	Stage of Technological Innovation (Nanotechnology)	7
10.8	Regulation as Driver/Barrier (Nanotechnology)	8
Correlation	on Matrices	
Exhibit Nu	umber	
10.9	Solution Providers – Measurement Barriers (Nanotechnology)	9
10.10	Measurement Barriers – Measurement Solutions (Nanotechnology)	10
10.11		
10.12	Stage of Technological Innovation – Measurement Barriers (Nanotechnology)	12
10.13	Stage of rechnological innovation – ineastrement Solutions (Nanotechnology)	13
10.14	Solution Providers – Stage of Technological Innovation (Nanotechnology)	14
10.15	Solution Providers – Stage of Technological Innovation (Nanotechnology) Stage of Technological Innovation – TI as Measurement Technology (Nanotechnology)	15
10.16	II as Measurement Technology – Measurement Barriers (Nanotechnology)	16
10.17	Solution Providers – TI as Measurement Technology (Nanotechnology)	17
10.18	II as Measurement Technology – Measurement Solutions (Nanotechnology)	18
10.19	Regulation as Driver/Barrier – Measurement Solutions (Nanotechnology)	19
10.20	Solution Providers – Regulation as Driver/Barrier (Nanotechnology)	20

Exhibit 10.1: MN Distribution of Measurement Barriers in Nanotechnology

			Data, Data			Lack of		Not				Small		Syste		ļ '
			Collection			Fundamental	Multiple	Standardi	Production	Reliabil	Resolut	market		ms-	Workforc	,
Acceptibility	Accessibility	Accuracy	& Retrieval	Destructive	Expense	Knowledge	Solutions	zed	Readiness	ity	ion	demand	Speed	level	е	Total
1	0	29	12	2	3	7	2	5	0	6	22	0	9	0	1	99



1

Exhibit 10.2: MN Distribution of Measurement Solution Providers in Nanotechnology

				Engineering													1
	Commercial			Management/C		Independent					National			Standards			ı l
	Calibration		Contractor	onsulting	Government	Testing/Certifica		Industry			Measure-	Small		Development	Testing		i l
Calibration	Service	Component	R&D Labs-for-	Firms/A&E	Laboratories	tion	Industrial R&D	Consortium/	Instrument	Material	ment	Business/I	Software	Organizations	Laboratorie	Universit	i l
Laboratories	Providers	Suppliers	Hire	Firms	and Agencies	Laboratories	Laboratories	Partnership	Suppliers	Suppliers	Institute	nventors	Developers	(SDO)	s	ies	Total
1	0	0	0	0	25	1	6	11	11	6	24	0	1	1	0	15	102

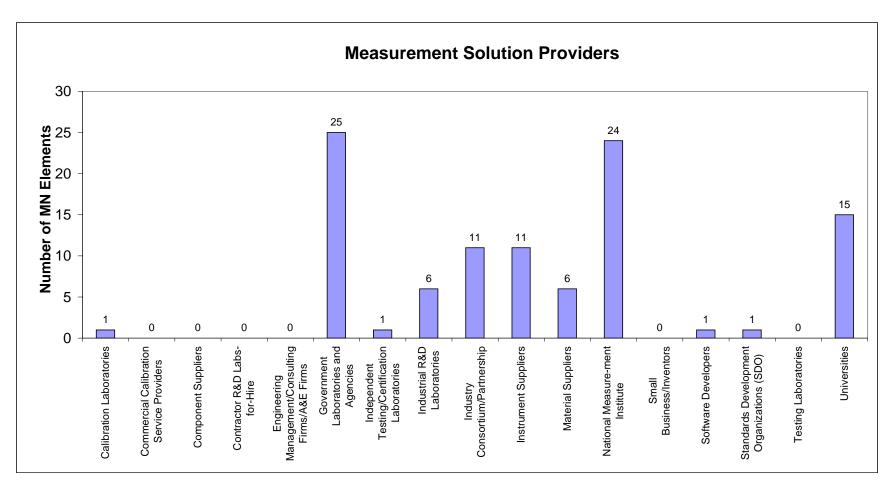


Exhibit 10.3: MN Distribution of Measurement Solutions in Nanotechnology

			Infrastruct	ure										Proc	lucts							Ser	vices		1
					Research -												Standard/cer		Test methods or	Validated				Third	
Coordin	at Data	Development -			Measure-				Computatio	Measure-	Measure-					l	tified	Test methods for	test data for	(hardened)		Expert	Intl	Party	1 1
ion/Faci	lit Collection/R	Measurement	Fund-amental		ment	Standar	User	Calibrati	nal	ment Instru-	ment	Metrics/Benc	Raw	Reference	Softwa	Stability	reference	production-scale	consumer	properties	Calibrati	consulta	Recognit	i Verifica	ä
ation	etrieval	Technology	Knowledge	Pro-tocols	Science	ds	Facility	on	Methods	ment	Method	hmarks	Data	Data	re	Tests	material	measurements	products	data	on	tion	on	on	Total
	0 1	23	1	4	13	3 9	2	4	6	12	8	2	4	1	0	0	7	2	0	() 1	C) () (100

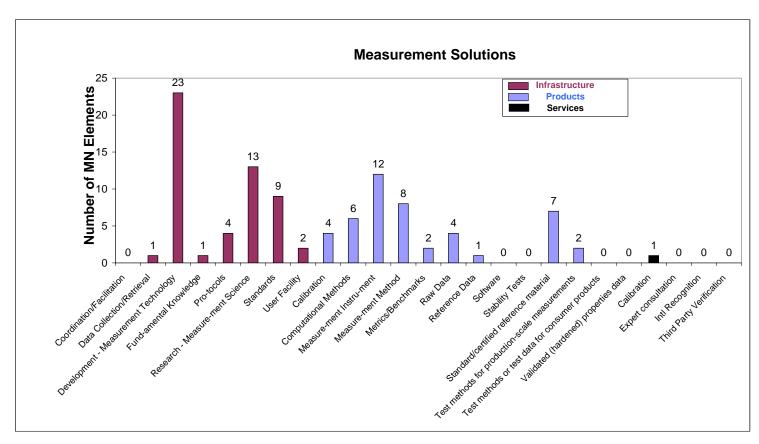


Exhibit 10.4: MN Distribution of Measurands in Nanotechnology

	Classi	cal					F	unctional					P	erformance			Struct	ural		<u> </u>
										Thermal-	Thermal-	Thermal-		Software						
			Physio-		Electronic/				Radio	Thermoch	Thermody	Thermop	Compu-tational	Per-	System Per-				1	l
Biological	Chemical	Physical	logical	Acoustical	Electrical	Magnetic	Optical	Photonic	frequency	emical	namic	hysical	Performance	formance	formance	Kinetic	Mechanical	Molecular	Spatial	Total
0	5	19	1	0	3	1	3	1	C	0	0	1	0	(0	0	1	1	0	36

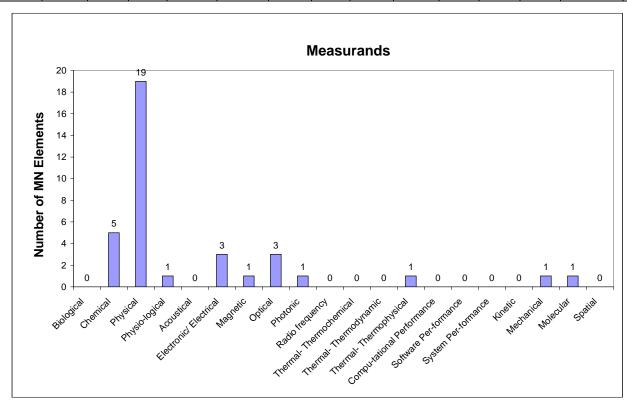


Exhibit 10.5: MN Distribution of Current Public/Private R&D Efforts in Nanotechnology

1	•	Both Public and Private Efforts Exist	No Efforts Exist
LITOI LO LAISE	LITOITS EXIST	I TIVALE ETIONS EXIST	INO EITOITS EXIST
1	8	5	22

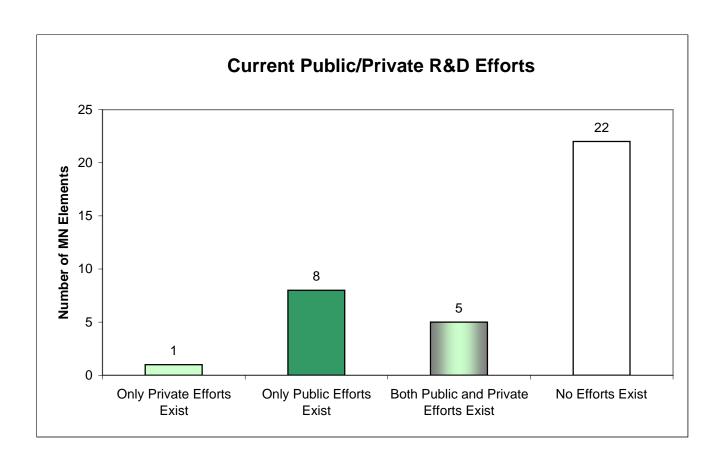


Exhibit 10.6: MN Distribution of TI as Measurement Technology in Nanotechnology

Technology Innovation	
is a Measurement	Technology Innovation is not a
Innovation	Measurement Innovation
15	21

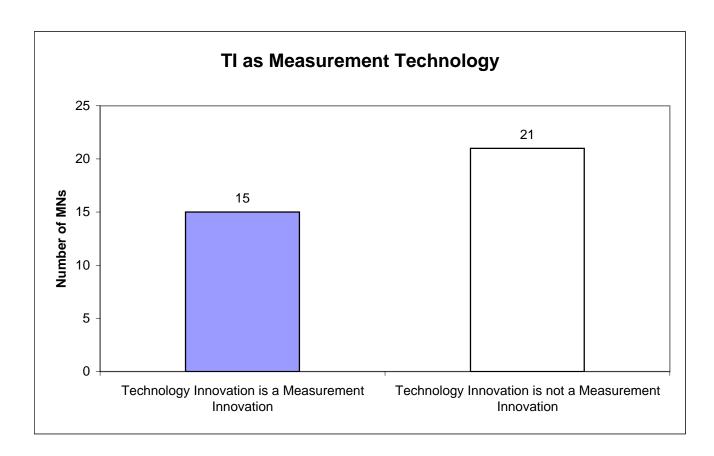


Exhibit 10.7: MN Distribution by Stage of Technological Innovation in Nanotechnology

Applied Research	Production	Market	End-use	Total
31	4	0	1	36

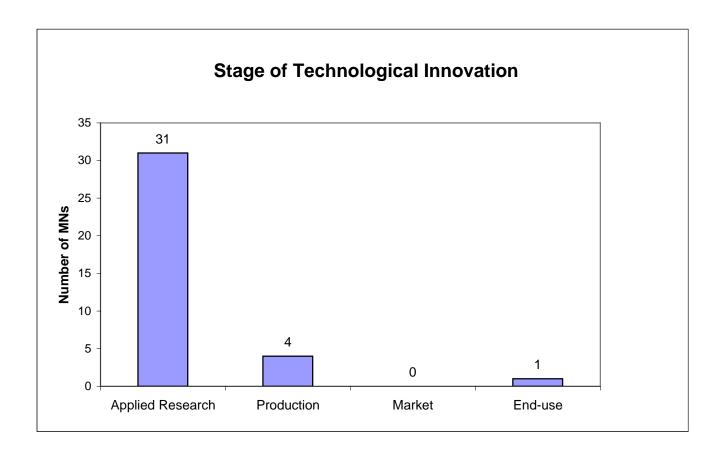


Exhibit 10.8: MN Distribution of Regulation as Driver/Barrier in Nanotechnology

MN Driver	MN Barrier	No Impact	
1	0	35	5

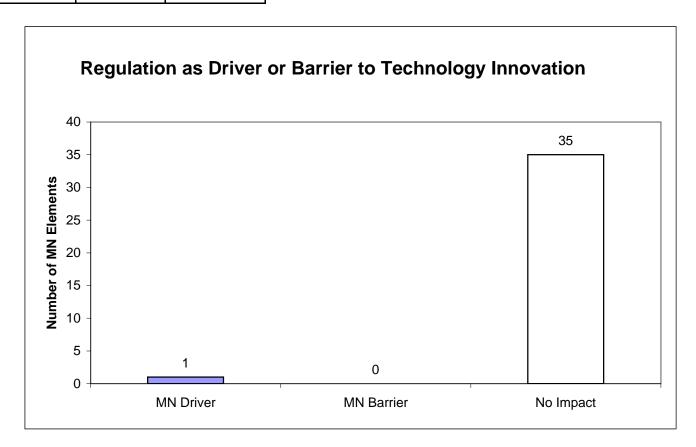


Exhibit 10.9: MN Correlation Matrix for Solution Providers and Measurement Barriers in Nanotechnology

	Acceptability/Compatibility Accuracy Data, Data Collection and/or Retrieval Destructive Expense Expense Multiple Solutions Exist Not Standardized Production Readiness Reliability Small Market Demand System-Level Problem System-Level Problem															
Solution Providers	Acceptability/Compatibility	Accessibility	Accuracy		Destructive	Expense	Lack of fundamental knowledge		Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Calibration laboratories			1		_	1	_	_	_							
Commercial calibration service providers																
Component suppliers																
Contractor R&D labs-for-hire																
Engineering management/consulting firms/A&E firms																
Government laboratories and agencies	1		19	8	1	3	5	1	1		3	18		8		1
Independent testing/certification laboratories				1					1					1		
Industrial R&D laboratories	1		5	2	1		2		1			5		1		
Industry consortium/partnership			10	3	1	1	-	1			3	7		5		
Instrument suppliers			10	4	1	1	2	1	3		2	5		2		
Material suppliers	1		4	4			2	1	2		1	1		1		
National Measurement Institute			20	7		2	5	1	4		5	15		5		1
Small business/inventors																
Software developers			1									1				
Standards development organizations (SDOs)			1	1								1				
Testing laboratories																
Universities			11	5	2	1	3	1			2	11		4		1

Exhibit 10.10: MN Correlation Matrix for Measurement Barriers and Measurement Solutions in Nanotechnology

									M	eas	ure	me	nt S	Solu	ıtio	ns									
			Inf	rastru	ıctı	ıre								F	Pro	duc	ts					S	erv	/ice	s
Measurement Solution Barriers	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Acceptability/Compatibility			1		1									1											
Accessibility																									
Accuracy		1	20		2	11	8	2	3	3	10	5	2	3	1			5	2	2		1			
Data, Data Collection/and or																									
Retrieval		1	5		4	3	3	1	2	3				3	1			3							
Destructive						1				1	2	2													
Expense			3			3	1				1							1							
Lack of Fundamental																									1
Knowledge			5	1	1	3	1		1	2	1	1	1	2				1							
Multiple Solutions Exist			2			1	1		1			1													Ш
Not Standardized			1		2		3		2	1	1	1						3							
Production Readiness																									
Reliability			4			3	2		1	1	3				1			2				1			
Resolution		1	15		1	8	4	2	1	3	9	6	2	2				2	2	2					
Small Market Demand																									
Speed			6		1	4	2			1	5	1						2	1						
System-Level Problem																									
Workforce																									

Exhibit 10.11: MN Correlation Matrix for Measurement Providers and Measurement Solutions in Nanotechnology

	Coordination/ facilitation Data Collection/ Retrieval Development for Measurement Technology Fundamental Scientific Knowledge Protocols Standards Computation Method Computation Method Measurement Instrument Measurement Method Measurement Method Metrics/ Benchmarks Raw Properties Data Reference Data Software Stability Tests Standard/CRM Test Methods - Consumer Products Validated Data Calibration Scale Test Methods - Consumer Products Validated Data Calibration Services Calibration Services Calibration Services Calibration Services																							
			Infi	rastr	uctu	re								F	rod	ucts					•,	Serv	ices	
Measurement Solution Providers	Soordination/ facilitation	Data Collection/ Retrieval	Development for Measurement fechnology	-undamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	Jser Facility	Salibration Method	Somputation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks		Reference Data	Software	Stability Tests	Standard/CRM	Fest Methods - Production Scale	/alidated Data	Salibration Services	Expert Consultation	International Recognition	3rd Party Verification
Calibration laboratories			1		ш	1	0)		U		_	_		ш.	ш.	0)	0)	1		 _	0	ш	_=	<u></u>
Commercial calibration service providers						•												•						
Component suppliers																								
Contractor R&D labs-for-hire																								
Engineering management/consulting																								
firms/A&E firms																								
Government laboratories and agencies		1	19	1	3	10	6	2	1	3	6	5	2	4				4	2					
Independent testing/certification laboratories					1		1											1						
Industrial R&D laboratories		1	4		2	1				1	2	1	1	2				1						
Industry consortium/partnership			7			6	2		1	1	8				1			2	1					
Instrument suppliers			7		1	4	5	2	3	2	3	2						1	1					
Material suppliers			4		2	3	4		1	1				2				1						
National Measurement Institute			15	1	1	7	6	2	4	4	10	6	2	1	1			6			1			
Small business/inventors																								
Software developers										1		1												
Standards development organizations (SDOs)		1	1		1																			
Testing laboratories																								
Universities			9	1		7	2		1	3	4	6	1	3	1			2	2					

Exhibit 10.12: MN Correlation Matrix for Stage of Technological Innovation and Measurement Barriers in Nanotechnology

					Me	easu	reme	ent S	olu	tion	Barrie	ers				
Stage of Technological Innovation	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	pəədS	System-Level Problem	Workforce
Applied Research	1		25	9	2	2	6	1	3		5	22		8		1
Production		,	3	3			1	1	2		1			1	Ī	
Market																
End-use			1			1										

Exhibit 10.13: MN Correlation Matrix for Stage of Technological Innovation and Measurement Solutions in Nanotechnology

									M	eas	urem	ent	So	luti	ons	3									
			Infr	astru	ctur	·e								Р	rod	uct	S					0,	Serv	/ice	s
Stage of Technological Innovation	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Applied Research		1	20	1	3	11	6	2	3	6	11	8	2	4				4	2			1			
Production			2		1	1	3		1		1				1			2							
Market																									
End-use			1			1												1							

Exhibit 10.14: MN Correlation Matrix for Solution Providers and Stage of Technological Innovation in Nanotechnology

	Stage of		nologi	cal
Measurement Solution Providers	Applied Research	Production	Market	End-Use
Calibration laboratories	_			1
Commercial calibration service providers				
Component suppliers				
Contractor R&D labs-for-hire				
Engineering management/consulting firms/A&E firms				
Government laboratories and agencies	23	1		1
Independent testing/certification laboratories		1		
Industrial R&D laboratories	6			
Industry consortium/partnership	9	2		
Instrument suppliers	9	2		
Material suppliers	3	3		
National Measurement Institute	21	2		1
Small business/inventors				
Software developers	1			
Standards development organizations (SDOs)	1			
Testing laboratories				
Universities	14	1		

Exhibit 10.15: MN Correlation Matrix for Stage of Technological Innovation and TI as Measurement Technology in Nanotechnology

Stage of Technological Innovation	TI as Measurement Technology
Applied Research	12
Production	2
Market	
End-use	1

Exhibit 10.16: MN Correlation Matrix for TI as Measurement Technology and Measurement Barriers in Nanotechnology

			1		Me	asu	reme	nt S	olut	ion l	Barrie	ers				
Innovation Equivalency	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Technology Innovation =	1		42	1	1		2	1	,	·	3)		2		
Measurement Innovation	ı I		13	4	1		3	1	2		3	9				

Exhibit 10.17: MN Correlation Matrix for Solution Providers and TI as Measurement Technology in Nanotechnology

Measurement Solution Providers	Technology Innovation = Measurement Innovation
Calibration laboratories	1
Commercial calibration service providers	
Component suppliers	
Contractor R&D labs-for-hire	
Engineering management/consulting firms/A&E firms	
Government laboratories and agencies	11
Independent testing/certification laboratories	1
Industrial R&D laboratories	3
Industry consortium/partnership	1
Instrument suppliers	4
Material suppliers	4
National Measurement Institute	9
Small business/inventors	
Software developers	1
Standards development organizations (SDOs)	
Testing laboratories	
Universities	7

Exhibit 10.18: MN Correlation Matrix for TI as Measurement Technology and Measurement Solutions in Nanotechnology

										Me	eası	ıren	nent	Sol	utio	ns									
			Infr	astr	uctu	ıre								Р	rodu	ıcts							Serv	ices	
Innovation Equivalency Technology Innovation = Measurement	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	8	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Innovation = Measurement			11		2	6	5		2	2	2	4	2	2				3				1			
	<u> </u>							-																	

Exhibit 10.19: MN Correlation Matrix for Regulation as Driver/Barrier and Measurement Solutions in Nanotechnology

										Me	easu	irem	ent	Sol	utio	ns									
			Infr	astr	uct	ure								Pro	odu	cts						ů,	Serv	ices	3
Regulatory Issues	Coordination/facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Regulation is a Driver			1			1												1							
Regulation is a Barrier																									

Exhibit 10.20: MN Correlation Matrix for Solution Providers and Regulation as Driver/Barrier in Nanotechnology

Measurement Solution Providers	Regulation is a Driver	Regulation is a Barrier
Calibration laboratories	1	
Commercial calibration service providers		
Component suppliers		
Contractor R&D labs-for-hire		
Engineering management/consulting firms/A&E firms		
Government laboratories and agencies	1	
Independent testing/certification laboratories		
Industrial R&D laboratories		
Industry consortium/partnership		
Instrument suppliers		
Material suppliers		
National Measurement Institute	1	
Small business/inventors		
Software developers		
Standards development organizations (SDOs)		
Testing laboratories		
Universities		

U.S. Measurement System

Measurement Need (MN) Data Book

Chapter 11. Software for Information Technology

Prepared by
Energetics Incorporated
for the
National Institute of Standards and Technology

April 2006

Reference List of MN Distribution Charts and MN Correlation Matrices

Distributi	ion Charts	Page
Exhibit Nu	umber	_
11.1	Measurement Barriers (Software for Information Technology)	1
11.2	Solution Providers (Software for Information Technology)	2
11.3	Measurement Solutions (Software for Information Technology)	3
11.4	Measurands (Software for Information Technology)	4
11.5	Current Public/Private R&D Efforts (Software for Information Technology)	5
11.6	IT as Measurement Technology (Software for Information Technology)	6
11.7	Stage of Technological Innovation (Software for Information Technology)	7
11.8	Regulation as Driver/Barrier (Software for Information Technology)	8
Exhibit Nu		
11.9	Solution Providers – Measurement Barriers (Software for Information Technology)	9
11.10		
11.11	Solution Providers – Measurement Solutions (Software for Information Technology)	11
11.12	Stage of Technological Innovation – Measurement Barriers (Software for Information Technology)	12
11.13	Stage of Technological Innovation – Measurement Solutions (Software for Information Technology)	13
11.14	Solution Providers – Stage of Technological Innovation (Software for Information Technology)	14
11.15	Stage of Technological Innovation – TI as Measurement Technology (Software for Information Technology)	15
11.16	TI as Measurement Technology – Measurement Barriers (Software for Information Technology)	16
11.17	Solution Providers – TI as Measurement Technology (Software for Information Technology)	17
11.18	TI as Measurement Technology – Measurement Solutions (Software for Information Technology)	18
11.19	Regulation as Driver/Barrier – Measurement Solutions (Software for Information Technology)	19
11.20	Solution Providers – Regulation as Driver/Barrier (Software for Information Technology)	20

Exhibit 11.1: MN Distribution of Measurement Barriers in Software for Information Technology

																		İ
				Data, Data			Lack of		Not				Small		Syste			İ
				Collection			Fundamental	Multiple	Standardi	Production	Reliabil	Resolut	market		ms-	Workforc	1	İ
4	Acceptibility	Accessibility	Accuracy	& Retrieval	Destructive	Expense	Knowledge	Solutions	zed	Readiness	ity	ion	demand	Speed	level	е	Total	j
Γ	9	3	13	13	0	0	8	1	15	1	10	0	0	2	0	0	75	ĺ

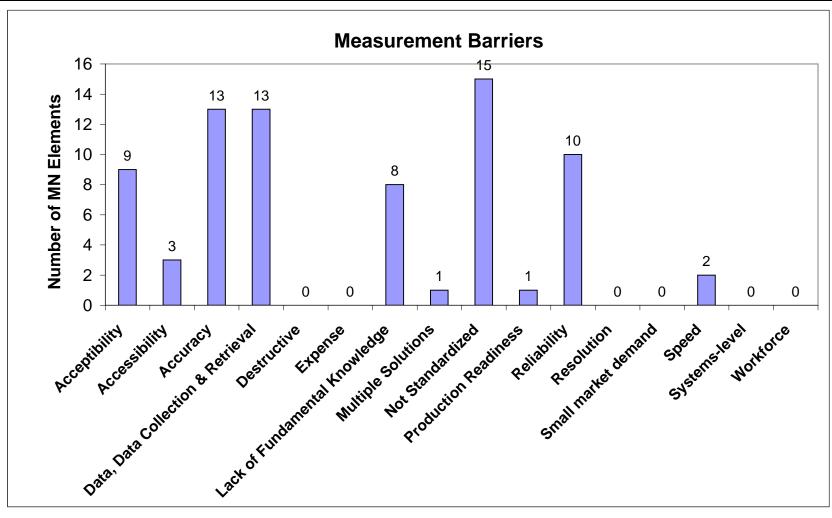


Exhibit 11.2: MN Distribution of Measurement Solution Providers in Software for Information Technology

				Engineering													
	Commercia	ı		Management/C		Independent								Standards			
	Calibration		Contractor	onsulting	Government	Testing/Certifica		Industry			National	Small		Development			
Calibratio	n Service	Component	R&D Labs-for-	Firms/A&E	Laboratories	tion	Industrial R&D	Consortium/	Instrument	Material	Measurement	Business/I	Software	Organizations	Testing		
Laborato	ies Providers	Suppliers	Hire	Firms	and Agencies	Laboratories	Laboratories	Partnership	Suppliers	Suppliers	Institute	nventors	Developers	(SDO)	Laboratories	Universities	Total
0	0	2	2	1	22	1	13	5	2	0	23	0	8	1	0	14	94

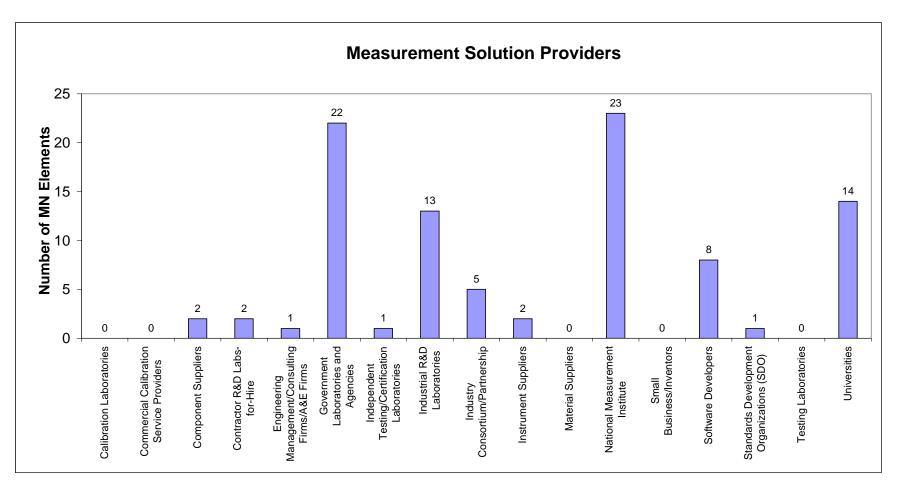


Exhibit 11.3: MN Distribution of Measurement Solutions in Software for Information Technology

			Infrastruct	ure										Proc	ducts							S	ervices		1
					Research -												Standard/ce		Test methods or	Validated					
Coor	dinat Data	Development -	Fund-		Measure-				Computati	Measure-	Measure-						rtified	Test methods for	test data for	(hardened)		Expert	Intl		
ion/F	acilit Collection	R Measurement	amental		ment	Standar	User	Calibra	onal	ment	ment	Metrics/Benc	Raw	Reference	Softw	Stability	reference	production-scale	consumer	properties	Calibrati	consulta	Recogniti	Third Party	
ation	etrieval	Technology	Knowledge	Protocols	Science	ds	Facility	tion	Methods	Instrument	Method	hmarks	Data	Data	are	Tests	material	measurements	products	data	on	tion	on	Verification	Total
4	3	5	2	5	5	8	1	1	7	1	8	15	1	9	3	0	1	1	3	1	0	1	0	1	86

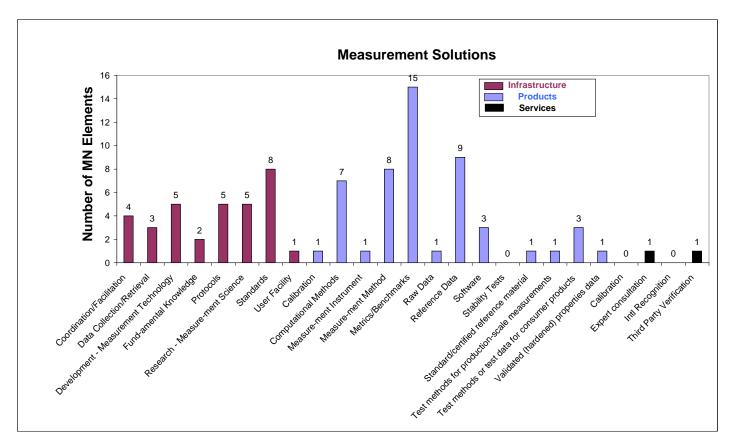


Exhibit 11.4: MN Distribution of Measurands in Software for Information Technology

	Classi	cal						Functional						Performance			Structi	ural		<u> </u>
										Thermal-	Thermal-	Thermal-								
			Physio-		Electronic/				Radio	Thermoch	Thermody	Thermoph	Compu-tational	Software	System					i l
Biological	Chemical	Physical	logical	Acoustical	Electrical	Magnetic	Optical	Photonic	frequency	emical	namic	ysical	Performance	Performance	Performance	Kinetic	Mechanical	Molecular	Spatial	Total
0	0	4	0	2	1	0	1	0	1	0	0	1	5	10	7	0	0	0	1	33

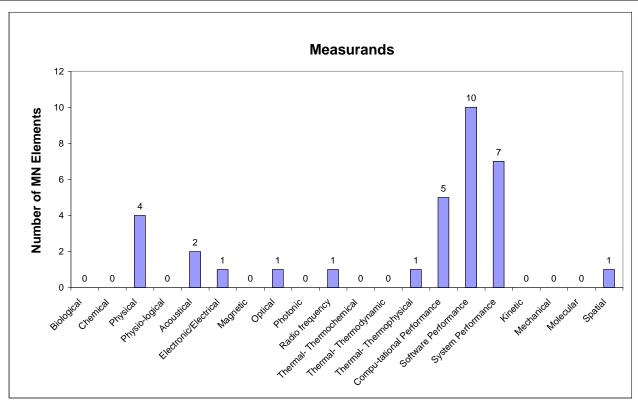


Exhibit 11.5: MN Distribution of Current Public/Private R&D Efforts in Software for Information Technology

Only Private	Only Public	Both Public and	
Efforts Exist	Efforts Exist	Private Efforts Exist	No Efforts Exist
1	3	8	21

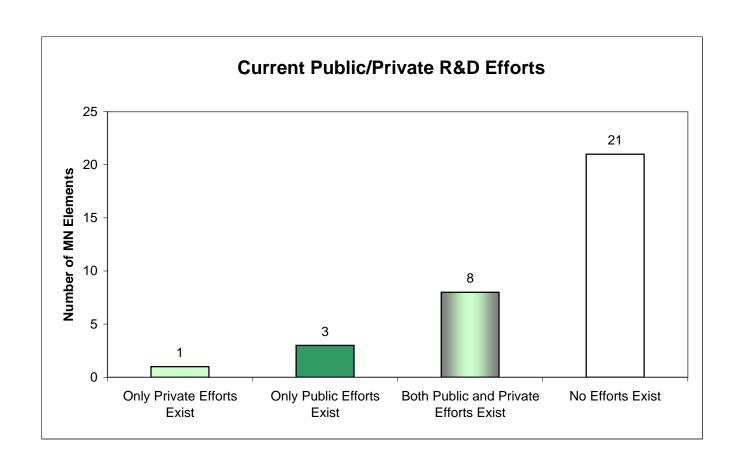


Exhibit 11.6: MN Distribution of TI as Measurement Technology in Software for Information Technology

Technology Innovation	
is a Measurement	Technology Innovation is not a
Innovation	Measurement Innovation
12	21

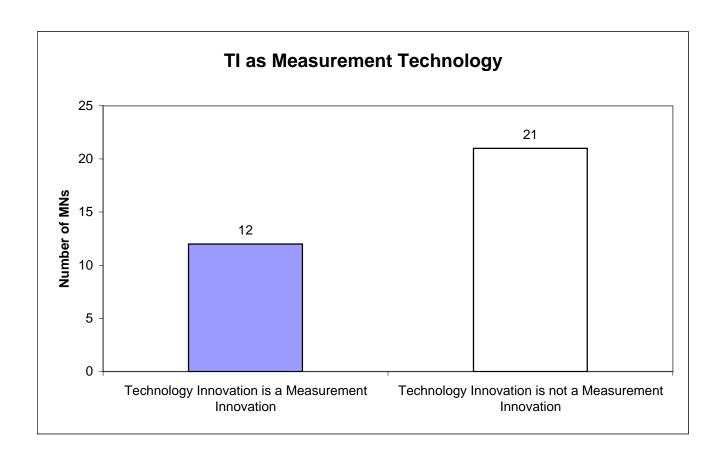


Exhibit 11.7: MN Distribution by Stage of Technological Innovation in Software for Information Technology

Applied Research	Production	Market	End-use	Total
21	4	5	3	33

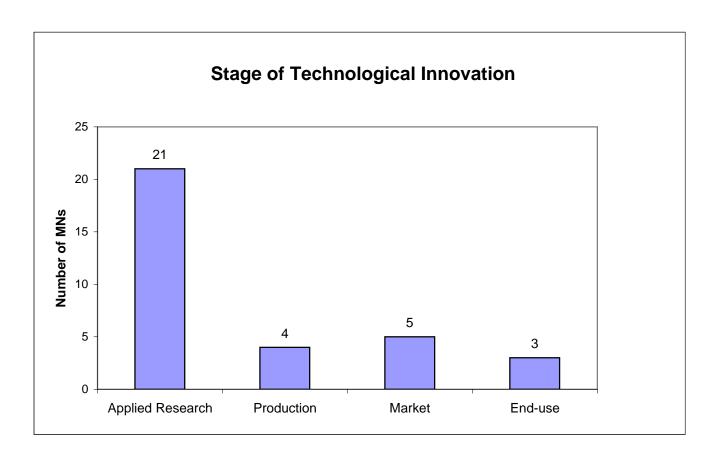


Exhibit 11.8: MN Distribution of Regulation as Driver/Barrier in Software for Information Technology

MN Driver	MN Barrier	No Impact
4	0	29

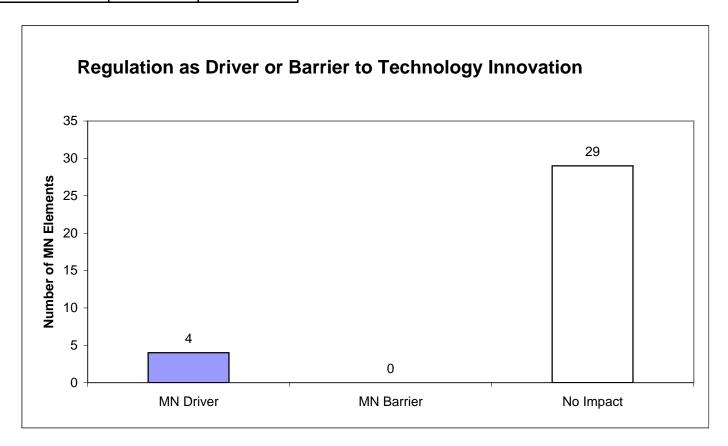


Exhibit 11.9: MN Correlation Matrix for Solution Providers and Measurement Barriers in Software for Information Technology

					Ме	asu	reme	nt S	olut	tion	Barrie	ers				
Solution Providers	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Calibration laboratories		_	_		_			_					- 0,	- 0,	- 0,	-
Commercial calibration service providers																
Component suppliers	2		1	1												
Contractor R&D labs-for-hire	1		2	1							2					
Engineering management/consulting firms/A&E firms		1														
Government laboratories and agencies	6		8	6			6	1	12	1	7			1		
Independent testing/certification laboratories											1					
Industrial R&D laboratories	2		2	2			6		6	1	2			1		
Industry consortium/partnership	4	1	1	2			1		5							
Instrument suppliers	2	1	1	1					1					Ì		
Material suppliers														Ì		
National Measurement Institute	6	3	8	8			6	1	14	1	6			1		
Small business/inventors																
Software developers	2	2	5	5			1		1		4					
Standards development organizations (SDOs)				1							1					
Testing laboratories																
Universities	2	1	7	8			4	1	2		6			2		

Exhibit 11.10: MN Correlation Matrix for Measurement Barriers and Measurement Solutions in Software for Information Technology

									M	eas	ure	me	nt S	Solu	ıtio	ns									
			Inf	rastru	ıctı	ıre								F	Pro	duc	ts					9,	Serv	/ice	s
Measurement Solution Barriers	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Acceptability/Compatibility	1		2		3				1	1		2			2	2			1			 		_	
Accessibility	1	1			1		1			1		1			1	1									一
Accuracy	2	1	2	1		2	3	1	1	4		4	8		2	1		1			3		1		
Data, Data Collection/and or																									
Retrieval	2	3	1	1	2	1	2	1		5	1	4	5	1	4	1		1			2 1				1
Destructive																									
Expense																									
Lack of Fundamental																									i
Knowledge	1	1	1	1	2	3	2			2		2	4		3										
Multiple Solutions Exist											1	1		1											
Not Standardized	2	1	3	1	3	2	5	1	1	2	1	2	5	1	5	2					1 1		1		
Production Readiness													1												
Reliability	2	1	1	1			2			2		2	7		3			1			2		1		1
Resolution																									
Small Market Demand																									
Speed			1				1					1	1		1										
System-Level Problem																									
Workforce																									

Exhibit 11.11: MN Correlation Matrix for Measurement Providers and Measurement Solutions in Software for Information Technology

										М	eası	ıren	nent	Sol	utior	าร									
			Inf	rastr	uctu	re								F	Prod	ucts						(Serv	ices	
Measurement Solution Providers	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Calibration laboratories	0				4	ш.	0		0	C				Ľ	Œ	0)	0)	()				-	ш		<u> </u>
Commercial calibration service providers																									$\overline{}$
Component suppliers					1					1		1	1						1						
Contractor R&D labs-for-hire	1						1					1	1							1					
Engineering management/consulting																									
firms/A&E firms												1				1									
Government laboratories and agencies	3	1	3	2	3	5	4		1	3	1	3	11	1	6	2		1	1	3			1		
Independent testing/certification laboratories													1												
Industrial R&D laboratories	1		3	1	3	3	2			3		2	7		4				1	1					
Industry consortium/partnership	1	1	1		2	1	3		1	1					1	2					1				
Instrument suppliers	1				1		1			1		1	1												
Material suppliers																							İ	j	
National Measurement Institute	1	2	5	2	4	2	7	1	1	3	1	6	10	1	6	3		1		1	1		1		
Small business/inventors																									
Software developers	1	2		1		1	1			3		2	4		3	1		1		1					1
Standards development organizations (SDOs)		-					1								1										1
Testing laboratories																									
Universities	3	2	2		1	3	3			5	1	5	6	1	4					2					1

Exhibit 11.12: MN Correlation Matrix for Stage of Technological Innovation and Measurement Barriers in Software for Information Technology

					Me	easu	reme	nt S	olut	ion l	Barrie	ers				
Stage of Technological	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	peeds	System-Level Problem	Workforce
Innovation	ď				Δ	Ē		Σ				Ř	S	S	Ś	3
Applied Research	4	3	10	11			6		6		6			1		
Production	2		1				1		3		1					
Market	3		1	2			1	1	4		1			1		
End-use		·	1				·	·	2	1	2	, and the second	·	·	·	

Exhibit 11.13: MN Correlation Matrix for Stage of Technological Innovation and Measurement Solutions in Software for Information Technology

									М	eas	urem	ent	: So	luti	ons	5										
			Infr	astru	ctur	e								Р	rod	uct	S						S	erv	ices	S
Stage of Technological Innovation	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	est Me	Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Applied Research	4	3	3	1	2	4	4	1		7		6	10		5	1		1			2	1				1
Production			1	1	2		2				·		1		2		Ť	Ť	1		1		Ī	Ī		
Market			1		1	1	2		1		1	1	1	1	2	2	Ť	Ť					Ī	Ī		
End-use											·	1	3							·				1		

Exhibit 11.14: MN Correlation Matrix for Solution Providers and Stage of Technological Innovation in Software for Information Technology

	Stage of		nologi	cal
Measurement Solution Providers	Applied Research	Production	Market	End-Use
Calibration laboratories				
Commercial calibration service providers				
Component suppliers	1	1		
Contractor R&D labs-for-hire	2			
Engineering management/consulting firms/A&E firms	1			
Government laboratories and agencies	10	4	5	3
Independent testing/certification laboratories				1
Industrial R&D laboratories	8	3	1	1
Industry consortium/partnership	2		3	
Instrument suppliers	2			
Material suppliers				
National Measurement Institute	13	3	4	3
Small business/inventors				
Software developers	7	1		
Standards development organizations (SDOs)	1			
Testing laboratories				
Universities	12		2	

Exhibit 11.15: MN Correlation Matrix for Stage of Technological Innovation and TI as Measurement Technology in Software for Information Technology

Stage of Technological Innovation	TI as Measurement Technology
Applied Research	8
Production	1
Market	3
End-use	

Exhibit 11.16: MN Correlation Matrix for TI as Measurement Technology and Measurement Barriers in Software for Information Technology

	Measurement Solution Barriers kist knowledge ge get and/or get an															
Innovation Equivalency	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Technology Innovation = Measurement Innovation	3	2	4	8			3	1	6		1			1		

Exhibit 11.17: MN Correlation Matrix for Solution Providers and TI as Measurement Technology in Software for Information Technology

Measurement Solution Providers	Technology Innovation = Measurement Innovation
Calibration laboratories	
Commercial calibration service providers	
Component suppliers	
Contractor R&D labs-for-hire	
Engineering management/consulting firms/A&E firms	1
Government laboratories and agencies	6
Independent testing/certification laboratories	
Industrial R&D laboratories	3
Industry consortium/partnership	3
Instrument suppliers	
Material suppliers	
National Measurement Institute	11
Small business/inventors	
Software developers	3
Standards development organizations (SDOs)	
Testing laboratories	
Universities	5

Exhibit 11.18: MN Correlation Matrix for TI as Measurement Technology and Measurement Solutions in Software for Information Technology

										Me	eası	ıren	nent	Sol	utio	ns									
			Infr	astr	uctu	ıre								Р	rodu	ıcts						;	Serv	ices	
Innovation Equivalency	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Technology Innovation = Measurement Innovation	1	3	2		2		3	1	1	3	1	4	3	1	5	3					1				
minovation		Ŭ					Ŭ			U			U		Ŭ	Ŭ									

Exhibit 11.19: MN Correlation Matrix for Regulation as Driver/Barrier and Measurement Solutions in Software for Information Technology

										N	leas	urei	men	t So	lutio	ons									
			Infr	astı	ruct	ure								Pro	odu	cts							Ser	vice	S
Regulatory Issues	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Regulation is a Driver	1				2		3		1			1			1	2									
Regulation is a Barrier																									

Exhibit 11.20: MN Correlation Matrix for Solution Providers and Regulation as Driver/Barrier in Software for Information Technology

Measurement Solution Providers	Regulation is a Driver	Regulation is a Barrier
Calibration laboratories		
Commercial calibration service providers		
Component suppliers		
Contractor R&D labs-for-hire	1	
Engineering management/consulting firms/A&E firms		
Government laboratories and agencies	2	
Independent testing/certification laboratories		
Industrial R&D laboratories		
Industry consortium/partnership	3	
Instrument suppliers	1	
Material suppliers		
National Measurement Institute	4	
Small business/inventors		
Software developers		
Standards development organizations (SDOs)		
Testing laboratories		
Universities	1	

U.S. Measurement System

Measurement Need (MN) Data Book

Chapter 12. Entire Economy

Prepared by
Energetics Incorporated
for the
National Institute of Standards and Technology

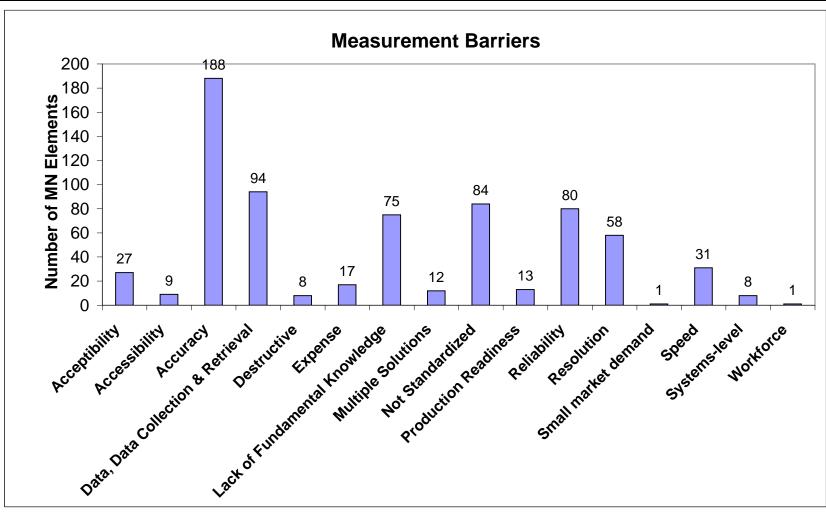
April 2006

Reference List of MN Distribution Charts and MN Correlation Matrices

Distribution	ion Charts	Page
Exhibit Nu		
12.1	Measurement Barriers (Entire Economy)	1
12.2	Solution Providers (Entire Economy)	2
12.3	Measurement Solutions (Entire Economy)	3
12.4	Measurands (Entire Economy)	4
12.5	Measurands (Entire Economy) Current Public/Private R&D Efforts (Entire Economy)	5
12.6	i as measurement i echnology (Entire Economy)	6
12.7	Stage of Technological Innovation (Entire Economy)	7
12.8	Regulation as Driver/Barrier (Entire Economy)	8
Correlatio	on Matrices	
Exhibit Nu		
12.9	Solution Providers – Measurement Barriers (Entire Economy)	9
12.10	Measurement Barriers – Measurement Solutions (Entire Economy)	10
12.11	Solution Providers – Measurement Solutions (Entire Economy)	11
12.12	Stage of Technological Innovation – Measurement Barriers (Entire Economy) Stage of Technological Innovation – Measurement Solutions (Entire Economy)	12
12.13	Stage of Technological Innovation – Measurement Solutions (Entire Economy)	13
12.14	Solution Providers – Stage of Technological Innovation (Entire Economy)	14
12.15	Stage of Technological Innovation – TI as Measurement Technology (Entire Economy)	15
12.16	TI as Measurement Technology – Measurement Barriers (Entire Economy)	16
12.17	Solution Providers – TI as Measurement Technology (Entire Economy)	17
12.18	TI as Measurement Technology – Measurement Solutions (Entire Economy)	18
12.19	Regulation as Driver/Barrier – Measurement Solutions (Entire Economy)	19
12.20	Solution Providers – Regulation as Driver/Barrier (Entire Economy)	20
12.21	Solution Providers – Regulation as Driver/Barrier (Entire Economy) Economic Sector/Technology Areas – Measurement Barriers (Entire Economy)	21
12.22	Economic Sector/Technology Areas – Measurands (Entire Economy) Economic Sector/Technology Areas – Stage of Technological Innovation (Entire Economy)	22
12.23	Economic Sector/Technology Areas – Stage of Technological Innovation (Entire Economy)	23
12.24	Economic Sector/Technology Areas – 11 as Measurement Technology (Entire Economy)	24
12.25	Economic Sector/Technology Areas – Measurement Solutions (Entire Economy)	25
12.26	Economic Sector/Technology Areas – Solution Providers (Entire Economy)	26
	r Measurement Need Distribution	
Exhibit Nu		
12.27	Distribution of Measurement Needs across Economic Sector/Technology Areas (Entire Economy)	27

Exhibit 12.1: MN Distribution of Measurement Barriers in Entire Economy

			Data, Data			Lack of		Not				Small		Syste		
			Collection			Fundamental	Multiple	Standardi	Production	Reliabil	Resolut	market		ms-	Workforc	1
Acceptibility	Accessibility	Accuracy	& Retrieval	Destructive	Expense	Knowledge	Solutions	zed	Readiness	ity	ion	demand	Speed	level	е	Total
27	9	188	94	8	17	75	12	84	13	80	58	1	31	8	1	706



1

Exhibit 12.2: MN Distribution of Measurement Solution Providers in Entire Economy

				Engineering													
	Commercial			Management/C		Independent								Standards			
	Calibration		Contractor	onsulting	Government	Testing/Certifica		Industry			National	Small		Development			
Calibration	Service	Component	R&D Labs-for-	Firms/A&E	Laboratories	tion	Industrial R&D	Consortium/	Instrument	Material	Measurement	Business/I	Software	Organizations	Testing		
Laboratories	Providers	Suppliers	Hire	Firms	and Agencies	Laboratories	Laboratories	Partnership	Suppliers	Suppliers	Institute	nventors	Developers	(SDO)	Laboratories	Universities	Total
5	1	18	4	3	221	11	98	66	76	15	221	0	15	39	2	109	904

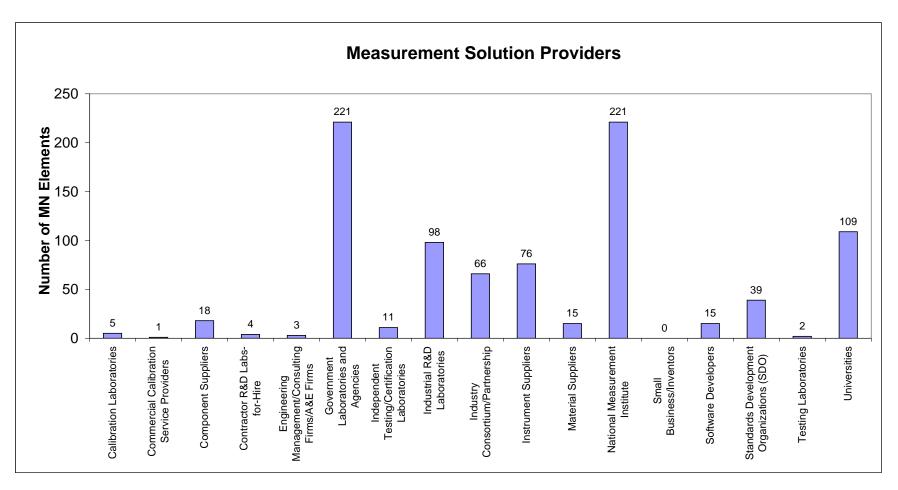


Exhibit 12.3: MN Distribution of Measurement Solutions in Entire Economy

			Infrastruct	ure				Products															Services						
				l	Research -												Standard/ce		Test methods or	Validated					1 1				
Coordi	nat Data	Development -	Fund-	l	Measure-				Computati	Measure-	Measure-						rtified	Test methods for	test data for	(hardened)		Expert	Intl		1 1				
ion/Fa	ilit Collection/R	Measurement	amental	l	ment	Standar	User	Calibra	onal	ment	ment	Metrics/Benc	Raw	Reference	Softw	Stability	reference	production-scale	consumer	properties	Calibrati	consulta	Recogniti	Third Party	1				
ation	etrieval	Technology	Knowledge	Protocols	Science	ds	Facility	tion	Methods	Instrument	Method	hmarks	Data	Data	are	Tests	material	measurements	products	data	on	tion	on	Verification	Total				
11	16	120	23	36	52	102	14	30	48	46	82	39	18	32	8	1	35	29	16	9	2	2	3	9	783				

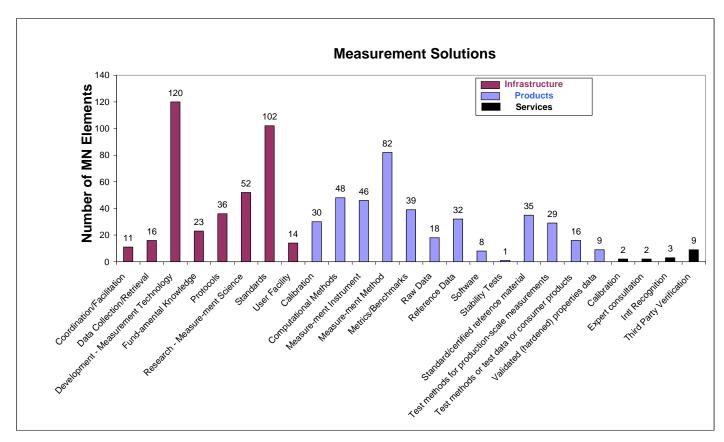


Exhibit 12.4: MN Distribution of Measurands in Entire Economy

		Cla	ssical						Functiona	l					Performance			Structu	ıral		
ſ											Thermal-	Thermal-	Thermal-					1	[[
						Electronic/				Radio	Thermoch	Thermody	Thermoph	Computational	Software	System			1		
	Biological	Chemical	Physical	Physiological	Acoustical	Electrical	Magnetic	Optical	Photonic	frequency	emical	namic	ysical	Performance	Performance	Performance	Kinetic	Mechanical	Molecular	Spatial	Total
Ī	24	26	73	8	3	37	15	22	13	6	2	9	14	7	12	23	1	15	7	5	322

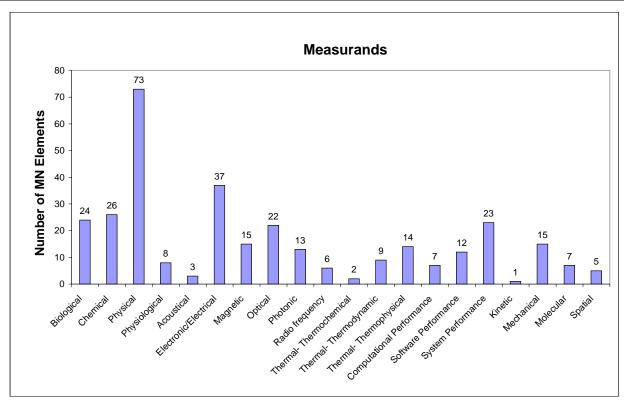


Exhibit 12.5: MN Distribution of Current Public/Private R&D Efforts in Entire Economy

Only Private Efforts Exist		Only Public Efforts Exist		Both Public and Private Efforts Exist	No Efforts Exist
	37	_	41	93	151

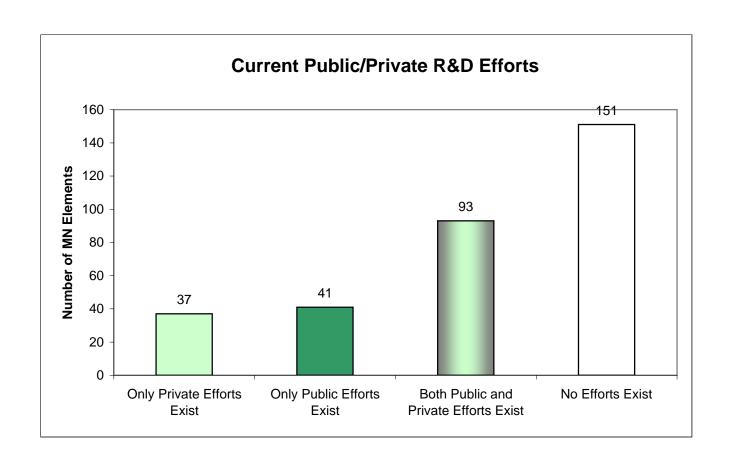


Exhibit 12.6: MN Distribution of TI as Measurement Technology in Entire Economy

	Technology Innovation is not a Measurement Innovation
136	186

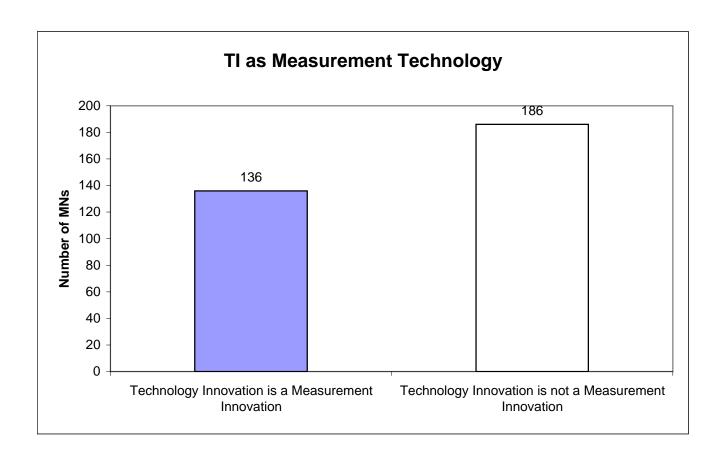


Exhibit 12.7: MN Distribution by Stage of Technological Innovation in Entire Economy

Applied Research	Production	Market	End-use	Total
227	42	41	12	322

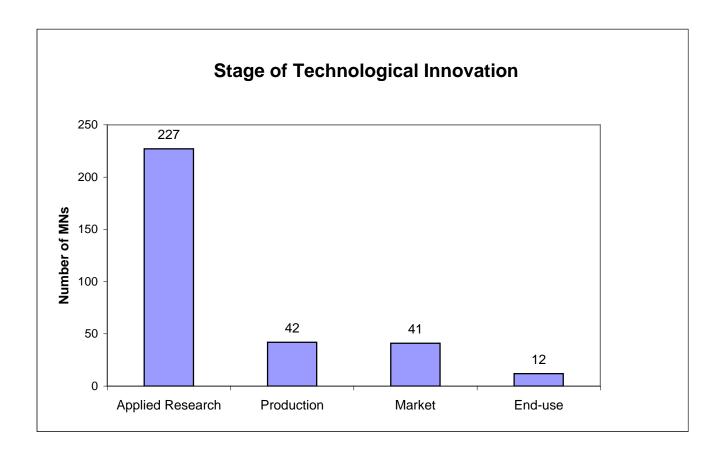


Exhibit 12.8: MN Distribution of Regulation as Driver/Barrier in Entire Economy

MN Driver	MN Barrier	No Impact
30	12	280

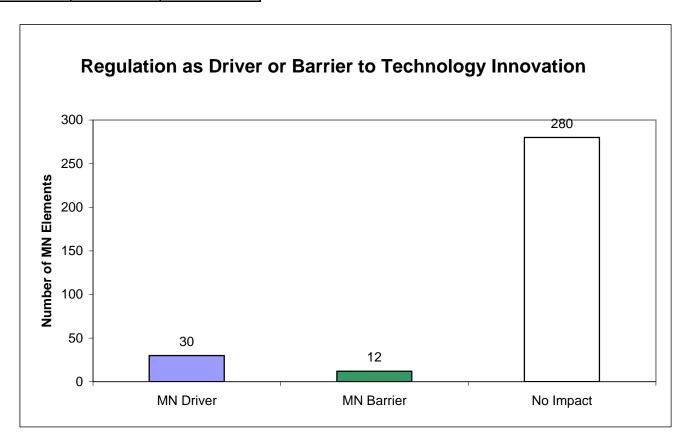


Exhibit 12.9: MN Correlation Matrix for Solution Providers and Measurement Barriers in Entire Economy

					Ме	asu	reme	nt S	olut	ion l	Barrie	ers				
Solution Providers	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Calibration laboratories	1		5	1		1			1		1					
Commercial calibration service providers				1					1							
Component suppliers	2		10	3		2	1	2	8		5	3				
Contractor R&D labs-for-hire	1		4	2			1		1		2					
Engineering management/consulting firms/A&E firms		1		1					1		1				1	
Government laboratories and agencies	13	4	128	51	4	11	58	6	51	10	48	44		22	5	1
Independent testing/certification laboratories	3		5	5			1		5		4			1		
Industrial R&D laboratories	7		51	17	3		31	4	27	4	19	20		7	2	
Industry consortium/partnership	7	4	40	22	3	8	15	2	17	2	18	14	1	13	2	
Instrument suppliers	9	3	49	21	2	5	14	1	22	6	19	16	1	4	2	
Material suppliers	2	1	7	9			5	2	7	1	2	2		2		
National Measurement Institute	17	8	130	64	6	10	50	7	61	10	58	39	1	22	8	1
Small business/inventors																
Software developers	4	2	9		1		1		3		5	2		1		
Standards development organizations (SDOs)	6	1	16	16	1	2	4	4	17	1	9	6		2	1	
Testing laboratories			1	1				1	2		1					
Universities	5	3	66	42	2	7	33	7	13	4	28	21		14		1

Exhibit 12.10: MN Correlation Matrix for Measurement Barriers and Measurement Solutions in Entire Economy

									M	eas	ure	me	nt S	Solu	utio	ns									
			Inf	rastru	ıctu	ıre								F	Pro	duc	ts					S	erv	ices	S
Measurement Solution Barriers	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Acceptability/Compatibility	2	2	6	1	4	3	15	1	3	2	2	5	5	1	3	2		3		3				3	1
Accessibility	2	1	1		1		3	1	3	1	1	5			1	1		1	1						1
Accuracy	4	8	86	7	18	35	59	12	26	23	32	47	20	13	12	3	1	25	14	6	3	2	2	1	4
Data, Data Collection/and or																									
Retrieval	6	15		6	12	11	31	8	10				11	11	12	2		12		11	7			1	6
Destructive	1		2	1	1	2	1		1	3								2			1				
Expense		3	7			6	6	1	3	2	6	3	1		1	1		4	3		1				1
Lack of Fundamental																									
Knowledge	2	3		20	6	_	15									2	1	8	5	2	1				
Multiple Solutions Exist		1	6	1		2	4		3		3			2										1	1
Not Standardized	4	1	15	3	17	6	47	2	9	7	8			5		5		13			5		1	1	5
Production Readiness			9	1	1	1					1	2		1	2				3						
Reliability	3	_		5										7	9	2	1	12	9	5	4	1	1		6
Resolution	1	2	40	4	3	12	12	7	5	10	14	16	4	4	2			4	4	1			1		
Small Market Demand							1						1					1							
Speed	1	2		1	4	6	_		1	6	13	11	1		3			4	1						
System-Level Problem	2	1	3		3	2	2		1			1	2			1			1	1					
Workforce			1	1								1													

Exhibit 12.11: MN Correlation Matrix for Measurement Providers and Measurement Solutions in Entire Economy

										Mea	sur	eme	nt S	olu	tions	5									
			Infr	astru	ctu	e								Pro	oduc	ts						9	Servi	ices	
	Coordination/ facilitation	ta Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Measurement Solution Providers	ပိ	Data	De	Ī	Pro	Re		Us		ပိ	Me	Me	Me	Ra	Re	So	Sta	Sta	Te	Ţ.	Va	Ca	X	Int	3rc
Calibration laboratories			1			1	3		2			1		1				1	1			1		1	
Commercial calibration service providers									1		1				1										
Component suppliers			6		2	2	9	1	1	1	3	4	2		1	1		1	2						2
Contractor R&D labs-for-hire	1						1		1	1	2	1	1					1		1	1				
Engineering management/consulting																									
firms/A&E firms	1	1			1							1				2		1		1					
Government laboratories and agencies	7	8	87	19	27	38	63	8	13	28	29	52	28	14	24	6	1	21	16	12	5	1	1		3
Independent testing/certification laboratories		4			1	•	,		4	0	,	4)	4	4			0	0	4				2	
	0	1	40	7	1	2 19	6 24	2	- 1	2	10	4	2 17	7	1	4		2	2		0		- 4		1
Industrial R&D laboratories	2		40	7	10			3		10	12	27		- /	11	1			10		2		1		
Industry consortium/partnership	1	3	26	4	9	13	23	2		12	18	_	6		4	4	4	8	8	_	6				
Instrument suppliers	2	_	37	8	10	13	28	3	11	11	11	12	4	4	3		1	8	10	3	1				2
Material suppliers	1	1	5	1	2	5	8	2	1	3	1	3	1	2	0.4	_		4	1	4.0	1			1	
National Measurement Institute	7	9	79	13	25	31	69	11	27	32	34	59	27	9	24	7	1	29	17	13	5	2	2	2	7
Small business/inventors																									
Software developers	2	3	1	2	1	1	3		1	7		4	5		3	1		2	1	1					1
Standards development organizations (SDOs)	2	4	8		8	1	22	1		2	1	12	6	1	2			9	7	4				2	4
Testing laboratories			1				2					1						1							1
Universities	3	7	45	11	3	24	25	4	10	25	17	35	14	11	14	1		7	8	3	4			1	2

Exhibit 12.12: MN Correlation Matrix for Stage of Technological Innovation and Measurement Barriers in Entire Economy

					Me	easu	reme	nt S	olut	ion I	Barrie	ers				
Stage of Technological Innovation	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	peeds	System-Level Problem	Workforce
Applied Research	12	7	142		7	11	65	9		8	50	50		25	4	1
Production	5	2	20	13	1	2	5	1	16	4	11	5		3	2	
Market	9		21	13		2	3	2	18		15	3	1	2	2	
End-use	1	·	5	2		2	2	, and the second	7	1	4		, and the second	1	, and the second	

Exhibit 12.13: MN Correlation Matrix for Stage of Technological Innovation and Measurement Solutions in Entire Economy

									M	eas	urei	mer	nt S	olu	tior	าร									
			Inf	rastru	ctu	re								Р	roc	luc	ts					0)	Serv	ices	`
Stage of Technological Innovation	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Applied Research	6	10	97	19	16	46	60	13	24	37	41	63	22	15	21	2	1	18	17	8	3 7	1	1	1	5
Production	3	3	14	3	5	1	17	1	3	5	2	6	2		5	1		7	5	4	1 1	1			2
Market	1	2	6	1	11	3	21		2	5	2	11	11	3	4	3		9	7	4	1 1			2	2
End-use	1	1	3		4	2	4		1	1	1	2	4		2	2		1					1		

Exhibit 12.14: MN Correlation Matrix for Solution Providers and Stage of Technological Innovation in Entire Economy

	Stage of		nologi	cal
Measurement Solution Providers	Applied Research	Production	Market	End-use
Calibration laboratories	2	1	1	1
Commercial calibration service providers	1			
Component suppliers	8	6	2	2
Contractor R&D labs-for-hire	4			
Engineering management/consulting firms/A&E firms	1	2		
Government laboratories and agencies	157	29	26	9
Independent testing/certification laboratories	4	3	3	1
Industrial R&D laboratories	76	12	7	3
Industry consortium/partnership	40	9	16	1
Instrument suppliers	55	13	7	1
Material suppliers	9	4	2	
National Measurement Institute	156	25	29	11
Small business/inventors				
Software developers	12	1	1	1
Standards development organizations (SDOs)	18	7	13	1
Testing laboratories	1		1	
Universities	93	8	8	

Exhibit 12.15: MN Correlation Matrix for Stage of Technological Innovation and TI as Measurement Technology in Entire Economy

Stage of Technological Innovation	TI as Measurement Technology
Applied Research	107
Production	11
Market	12
End-use	6

Exhibit 12.16: MN Correlation Matrix for TI as Measurement Technology and Measurement Barriers in Entire Economy

					Me	asu	reme	nt S	olut	ion l	Barrie	ers				
Innovation Equivalency	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	peeds	System-Level Problem	Workforce
Technology Innovation =		4	00	40	0	•	00	1	00		00	00		0	0	
Measurement Innovation	9	4	90	48	2	8	36	5	38	4	33	29		9	3	

Exhibit 12.17: MN Correlation Matrix for Solution Providers and TI as Measurement Technology in Entire Economy

Measurement Solution Providers	Technology Innovation = Measurement Innovation
Calibration laboratories	5
Commercial calibration service providers	1
Component suppliers	4
Contractor R&D labs-for-hire	2
Engineering management/consulting firms/A&E firms	2
Government laboratories and agencies	89
Independent testing/certification laboratories	4
Industrial R&D laboratories	35
Industry consortium/partnership	20
Instrument suppliers	38
Material suppliers	8
National Measurement Institute	103
Small business/inventors	
Software developers	8
Standards development organizations (SDOs)	12
Testing laboratories	1
Universities	42

Exhibit 12.18: MN Correlation Matrix for TI as Measurement Technology and Measurement Solutions in Entire Economy

										M	eası	ıren	nent	So	lutio	ns									
			Infr	astr	uctu	ıre								Р	rodu	ıcts						;	Serv	ices	,
Innovation Equivalency	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Technology Innovation = Measurement	4	11	46	7	15	24	48	7	20	19	23	34	11	10	16	8	1	16	13	6	5	2	1	1	3
Innovation	-	11	+0	- 1	10	24	+0	- /	20	19	23	94	- ' '	10	10	U	- '	10	13	,	J		١,	'	J

Exhibit 12.19: MN Correlation Matrix for Regulation as Driver/Barrier and Measurement Solutions in Entire Economy

										N	leas	urer	nen	t So	lutio	ns									
			Infr	astr	uct	ure								Pro	oduc	ts							Ser	vice	S
Regulatory Issues	Coordination/facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Regulation is a Driver	2	2	5		6	5	14		2	4	3	8	3	2	2	5		6	7	1	2				2
Regulation is a Barrier		4					7		1	5	1	2	3	1	2			3	2	1				2	2

Exhibit 12.20: MN Correlation Matrix for Solution Providers and Regulation as Driver/Barrier in Entire Economy

Measurement Solution Providers	Regulation is a Driver	Regulation is a Barrier
Calibration laboratories	1	2
Commercial calibration service providers		
Component suppliers		
Contractor R&D labs-for-hire	1	
Engineering management/consulting firms/A&E firms	1	
Government laboratories and agencies	20	6
Independent testing/certification laboratories	3	3
Industrial R&D laboratories	8	2
Industry consortium/partnership	10	2
Instrument suppliers	3	2
Material suppliers		2
National Measurement Institute	25	10
Small business/inventors		
Software developers		
Standards development organizations (SDOs)	5	2
Testing laboratories		1
Universities	8	3

Exhibit 12.21: MN Correlation Matrix for Economic Sector/Technology Areas and Measurement Barriers in Entire Economy

In Entire Economy				М	eas	urer	nent	So	lutio	on B	arri	ers				
Economic Sector/Technology Areas	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Agriculture and Food Processing			5	2			_	-	1	_	3	1	- 0,	- 0,	0,	-
Building and Construction - Civil Infrastructure	2		3	6			3	1	3		2				1	
Building and Construction - Residential / Commercial Building	3		7	13		1	4	3	9	1	5	1		1	1	
Chemical			3	3			1				1	1				_
Defense	1	1	10	4		2	6		4		5	1		1		
Electronics - Non-semiconductor	4	4	40	13		4	12	3	19	8	13	10		4		
Electronics - Semiconductor	2	1	38	8	1	6	13		3	2	12	22		13		
Energy and Power - Fossil fuel	1		2				1							1		
Energy and Power - Hydrogen			2	5	1		3		4	1	1	1				
Energy and Power - Nuclear			1								1					
Energy and Power - Power Generation and Distribution	1	1	8	7			2	1	4		3	1		1		
Energy and Power - Renewable			2	1			1									
Environment			2	6			1		3		2	1				
Healthcare - Bioimaging and Informatics	4		23	10		4	14	2	8	1	8	7		2	2	
Healthcare - Clinical Diagnostics	3	1	26	10		4	13	2	12		12	5		2	1	
Healthcare - Health and Safety	1		13	6			8	1	6		5	3		1	2	
Healthcare - Pharmaceuticals	2		16	8	1	2	8	2	5		10	5		3		1
Homeland Security - First Responders	4		12	10		1	5		16	1	8	3	1	3		
Industrial Biotechnology	2	1	3	4	1	3	3	1	2		1	1		3		
Information Technology - Software	9	3	-	13			8	1	15	1	10			2		
Information Technology - Hardware	2		16	3	1	3			8	1	4	4		5	1	
Manufacturing - Continuous	1	1	5	7		_	3	1	2	1	5	2			1	
Manufacturing - Discrete	2	2		7	2	2	2		3	_	5	8		3	1	
Materials - Ceramics	-	0	5		_	1	4	1	0	2	1	3				
Materials - Metals	2	1	10	8	1	1	1	2	2		2	5 5		1		1
Materials - Polymers	2	1	44	16	2	6	9	1	20	2	17	19		10	2	1
Measurement Technology - Instrumentation	5	1		16 9	2	ь	3	1		1	17 5			10	2	
Measurement Technology - Process Control Measurement Technology - SI Units	0	1	11	4	1	1	2		5 4		7	3 4		4	- 1	
Nanotechnology Nanotechnology	1	- 1	29	12	2	3	7	2	5		6	22		9		1
Other	1	1	29 1	12		3	1				0	1		9		
Other - Law Enforcement	1	- 1					1					1				-
Telecommunications	3	1	13	7	1		3		8	1	10	3		2	4	-
Transportation - Aerospace	1	1	9	4		2	3	2	3	-	6	3			4	_
Transportation - Automotive	3	2	11	15	2	2	5	2	7	1	9	3		2		_
Transportation - Automotive	3		- 11	13			J		- /	- 1	3	3				

Exhibit 12.22: MN Correlation Matrix for Economic Sector/Technology Areas and Measurands in Entire Economy

in Entire Economy	_																			
		Clas	sica	ı				Fur	nctic	nal				Per	forma	nce	S	Struc	tura	ıl
Economic Sector/Technology Areas	Biological	Chemical	Physical	Physiological	Acoustical	Electronic/Electrical	Magnetic	Optical	Photonic	Radio frequency	Thermal-Thermochemical	Thermal-Thermodynamic	Thermal-Thermophysical	Computational Performance	Software Performance	System Performance	Kinetic	Mechanical	Molecular	Spatial
Agriculture and Food Processing	2	1	1			1														
Building and Construction - Civil Infrastructure			1						1			1	2	1				2		1
Building and Construction - Residential / Commercial Building		1	3	2		3			1			1	4	1		3		2		2
Chemical		2										1	1						\neg	
Defense	1	2				1		2	1							2	1	Πİ	\neg	
Electronics - Non-semiconductor		4	22	1		17	9	5	4	2		2	2	1		1		3	2	1
Electronics - Semiconductor		3	19			13	3		1	1			2					2	2	
Energy and Power - Fossil fuel		1	2																	
Energy and Power - Hydrogen		2	1			1					2							1		
Energy and Power - Nuclear			1																	
Energy and Power - Power Generation and Distribution		1	3			4	2					1	1							
Energy and Power - Renewable						1		1												
Environment			1		1	2		1	1									Ш		
Healthcare - Bioimaging and Informatics	8			3			6		1						4	4		1	1	
Healthcare - Clinical Diagnostics	19			2			2	_	2					1	1	3		1	1	
Healthcare - Health and Safety	4					2		2	1	1		1	1			1		1		Ш
Healthcare - Pharmaceuticals	10					1			1			2						ш	1	ш
Homeland Security - First Responders	1				2		3	2	1	2			1			7		1		1
Industrial Biotechnology	4	3																ш		Щ
Information Technology - Software			4		2			1		1			1	5	10	7		Щ		1
Information Technology - Hardware		1	10			3		1		2				2		6		1		\vdash
Manufacturing - Continuous	-					1	1	2					2	1	1			2		_
Manufacturing - Discrete	╀	_	8					1	_				2	1	1	1	1	2		1
Materials - Ceramics	╀	1	-				_	<u> </u>	1			1	2			1			3	ш
Materials - Metals	1	3				_	3		1	_		_				1		3		$\vdash\vdash$
Materials - Polymers	6	5		1 2	1	4 5		5	3	1		3	0		1	1 5		2	2	2
Measurement Technology - Instrumentation	Ь	2			- 1	0		5	3	1		3	3 1		1	5		2	- 1	3
Measurement Technology - Process Control Measurement Technology - SI Units	1		4	1	1	1		2	1	1		1	1			4		2		
Nanotechnology Nanotechnology	\vdash	5		1		3	1	3	1	_	H	- 1	1					1	1	\vdash
Other	1	1		_	1			1	-			1	-1							\vdash
Other - Law Enforcement	\vdash	1		\vdash				1				- 1						H	\dashv	\Box
Telecommunications	\vdash	1		\vdash	1	4		1	3	3						7		1	\dashv	一
Transportation - Aerospace	\vdash	1			-	_		2				1		1		1	1	3	\neg	
Transportation - Automotive	t	2		2		1		_		1	1	1		1		1		3	\dashv	3
Transportation - Automotive	-		J	_							_	_ '								

Exhibit 12.23: MN Correlation Matrix for Economic Sector/Technology Areas and Stage of Technological Innovation in Entire Economy

•	Ctama	of Tools and	!! !	
	Stage		ogical Inno	vation
Economic Sector/Technology Areas	Applied Research	Production	Market	End-use
Agriculture and Food Processing	2		2	1
Building and Construction - Civil Infrastructure	6	1	2	
Building and Construction - Residential / Commercial Building	13	1	8	1
Chemical	4			
Defense	13	1		
Electronics - Non-semiconductor	49	14	11	2
Electronics - Semiconductor	44	6	1	1
Energy and Power - Fossil fuel	2		1	
Energy and Power - Hydrogen	5	1	1	
Energy and Power - Nuclear	1			
Energy and Power - Power Generation and Distribution	7	2	2	1
Energy and Power - Renewable	1		1	
Environment	5		2	
Healthcare - Bioimaging and Informatics	21	2	9	2
Healthcare - Clinical Diagnostics	22		12	2
Healthcare - Health and Safety	16	2	3	
Healthcare - Pharmaceuticals	19	3	2	
Homeland Security - First Responders	19	1	3	2
Industrial Biotechnology	6	2	1	
Information Technology - Software	21	4	5	3
Information Technology - Hardware	24		1	2
Manufacturing - Continuous	6	3	1	
Manufacturing - Discrete	14	3		1
Materials - Ceramics	8	2		
Materials - Metals	6	6	1	
Materials - Polymers	19	2	2	
Measurement Technology - Instrumentation	48	4	6	2
Measurement Technology - Process Control	10	5		1
Measurement Technology - SI Units	11	2	2	
Nanotechnology	31	4		1
Other	3		1	
Other - Law Enforcement	2			_
Telecommunications	15	1	4	2
Transportation - Aerospace	7	2	1	1
Transportation - Automotive	15	6	2	1

Exhibit 12.24: MN Correlation Matrix for Economic Sector/Technology Areas and TI as Measurement Technology in Entire Economy

Economic Sector/Technology Areas	Technology Innovation = Measurement Innovation
Agriculture and Food Processing	2
Building and Construction - Civil Infrastructure	3
Building and Construction - Residential / Commercial Building	7
Chemical	2
Defense	8
Electronics - Non-semiconductor	17 18
Electronics - Semiconductor	
Energy and Power - Fossil fuel Energy and Power - Hydrogen	3
Energy and Power - Nuclear	1
Energy and Power - Nuclear Energy and Power - Power Generation and Distribution	4
Energy and Power - Renewable	-
Environment	3
Healthcare - Bioimaging and Informatics	22
Healthcare - Clinical Diagnostics	27
Healthcare - Health and Safety	8
Healthcare - Pharmaceuticals	15
Homeland Security - First Responders	14
Industrial Biotechnology	3
Information Technology - Software	12
Information Technology - Hardware	5
Manufacturing - Continuous	7
Manufacturing - Discrete	13
Materials - Ceramics	4
Materials - Metals	2
Materials - Polymers	6 41
Measurement Technology - Instrumentation	11
Measurement Technology - Process Control Measurement Technology - SI Units	10
Nanotechnology	15
Other	2
Other - Law Enforcement	1
Telecommunications	9
Transportation - Aerospace	5
Transportation - Automotive	11

Exhibit 12.25: MN Correlation Matrix for Economic Sector/Technology Areas and TI as Measurement Technology in Entire Economy

										Ma		rom	ont	Sol		no									\neg
	-									IVIE	asu	ren	lent								1				-
	-		Infi	ast	ruct	ure								Pro	odu	cts		1	1	- 1		- 1	Serv	ices	
	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	nternational Recognition	3rd Party Verification
Economic Sector/Technology Areas Agriculture and Food Processing	ŭ	۵	۵	F١	4	2	ن 1	ñ	<u>ပိ</u>	ŏ	<u>Š</u>	_	Š	ĸ	1	Š	Şŧ	_	ř	Ĕ	Š	ပၱ	Û	Ē	ñ
Building and Construction - Civil Infrastructure		1	3	1	1	3	4			3	1	2	2		1			1	1		1				
Building and Construction - Residential / Commercial Building	+	2	5	2	2	6	11			7	2	7	5	2	3			1	2	4	2				1
Chemical	1	1	1	1		1	1	1		2	1	'	J		3			_		4					
Defense	-	1	2	3		2	2	2	3		4	5	1	3	2		1	2	2		1			-	1
Electronics - Non-semiconductor	1		34	5	8	8	28	3	7	7	8	12	3	2	3	1	_	3	9	1	2			1	3
Electronics - Non-semiconductor Electronics - Semiconductor	-		31	2	2	12	8	5	7	10	16	13	1	3	2	1		7	6	-	1	1	1		1
Energy and Power - Fossil fuel	+		31			12	1	3	1	10	10	1		3	1	-		-/	O			-		1	
Energy and Power - Hydrogen	1		2	1		1	3	1	_		1	1	1	2	-				3	1	1			-	
Energy and Power - Nuclear	-		1			1	J	•	1		-	-							J	_				-	\dashv
Energy and Power - Power Generation and Distribution	1	1	2		1	1	4	2	3	4		3		3	1			2	2	1	1	1		1	-
Energy and Power - Renewable			1	1	_	2	4		3	4		3		J	-				1	_					-
Environment	+	1	1	1		1	2		3	3	1	1	1	1	1				2						1
Healthcare - Bioimaging and Informatics	2	3	10	_	9	6	12	2	4	4	6	9	7	2	3	4		7	5	1	2				_
Healthcare - Clinical Diagnostics		4	8	4	7	9	13	2	3	4	4	11	4	3	7	5		10	3	_	1				1
Healthcare - Health and Safety	1	4	7	1	4	1	7		5	3	3	7	2	1	4	3	1	2	3	5			\vdash		
Healthcare - Pharmaceuticals		3	10	5	3	7	10	1	3	2	2	11	2	_	4			5	1	1			\vdash		=
Homeland Security - First Responders		1	6	1	4	1	8		3	4	6	9	6	2	3			3	1	6	1		1		2
Industrial Biotechnology	_		3	2	1	2	3	1	2	4	2	6	U		1			2	1	1	-		-		
Information Technology - Software	4	3	5	2	5	5	8	1	1	7	1	8	15	1	9	3		1	1	3	1		1		1
Information Technology - Software	2	J	13	1	2	7	9	1	1	3	2	8	5	<u> </u>	2	J		3	2	2	•		-		-
Manufacturing - Continuous	2	3	3	1	É	1	4	1	2	2	2	1	,		2	1		J	-	1			H		2
Manufacturing - Continuous Manufacturing - Discrete	2	2	6	1		•	4	2	4	3	7	6	1		2	1		3	2	1			1		2
Materials - Ceramics		1	5	1		1	1	1	_	2	<u> </u>	2	1		3			5	-	-				1	
Materials - Geranics Materials - Metals	2	1	4	_		2	4	1	1	5		6	_		1			3	2		1		\vdash	2	1
Materials - Netrals Materials - Polymers		1	9	5	4	5	7	1		3	2	10	1	5	1			1			-		\vdash	1	1
Measurement Technology - Instrumentation	2	3	27	3	10	12	24	2	9	8	15	11	5	4	5	3	1	6	3	8	1		H	-	2
Measurement Technology - Process Control	1	1	9	1	3	12	5	1	1	2	4	4	2	1	1	3		2	5	1	_		1		_
Measurement Technology - SI Units		1	5	2	3	1	4		5	4	5	3	2	-		1		2	J			1			\dashv
Nanotechnology	+	1	23	1	4	13	9	2	4	6	12	8	2	4	1			7	2			1	\vdash		\dashv
Other	+	-	23	_		10	1		_	1	12	2		1	1	1		-				•	\vdash		\dashv
Other - Law Enforcement	+	\vdash	—	 	 			H		1	 				1								H		\dashv
Telecommunications	1		11	-	6	4	8	1	3	1	2	11	5					1	3	2			1		\dashv
Transportation - Aerospace	2	2	3	1	U	1	2	1	3	2	3	2	2					3	5					-	1
Transportation - Automotive	3	4	6	3		5	9	2	3	7	3	4	1	4				1	7	1	2		\vdash		3
Transportation Automotive	J	7	U	٥		٥	9	_	J		J	7		7					- 1						J

Exhibit 12.26: MN Correlation Matrix for Economic Sector/Technology Areas and TI as Measurement Technology in Entire Economy

							Solu	tion	Pro	vide	ers						
					ns												
Economic Sector/Technology Areas	Calibration laboratories	Commercial calibration service providers	Component suppliers	Contractor R&D labs-for-hire	Engineering management/consulting firms/A&E firms	Government laboratories and agencies	Independent testing/certification laboratories	Industrial R&D laboratories	Industry consortium/partnership	Instrument suppliers	Material suppliers	National Measurement Institute	Small business/inventors	Software developers	Standards development organizations (SDOs)	Testing laboratories	Universities
Agriculture and Food Processing	۲	U	٥	U		4	_	1	1	2		4	0)	0)	1		-
Building and Construction - Civil Infrastructure			1			3	2		5	2	1	4		1	2	1	3
Building and Construction - Residential / Commercial Building			2			11	3	5	7	3	1	15		1	8	1	8
Chemical						4		1	1	1		3		1			1
Defense			1	1		9		3		4	1	12		1			6
Electronics - Non-semiconductor			12	1		53	2	19	14	29	2	41		2	7		33
Electronics - Semiconductor	1			1		34		16	22	10	2	38		2	1		19
Energy and Power - Fossil fuel	1					2	1	1				3					
Energy and Power - Hydrogen	1					6		5		1		6			1		
Energy and Power - Nuclear										1		1					
Energy and Power - Power Generation and Distribution	3					6	1	3		1	2	10			1		5
Energy and Power - Renewable						2		2							1		1
Environment		1	1			5	1	2	2	1		3		1	1		3
Healthcare - Bioimaging and Informatics			1		1	26		14	8	5	1	26		1	6		10
Healthcare - Clinical Diagnostics			1			26	1	12	10	6	2	24		2	4	1	14
Healthcare - Health and Safety	1					13	1	8	4	4		19			4		6
Healthcare - Pharmaceuticals	1					15	2	7	4	6		14		1	4		15
Homeland Security - First Responders		1		2	1	18		4	3	9		22		1	5		5
Industrial Biotechnology						6	1		5	2		6			2		4
Information Technology - Software			2	2	1	22	1	13	5	2		23		8	1	ш	14
Information Technology - Hardware	1		2	1		21		13	6	4	1	14		1	2	Ш	13
Manufacturing - Continuous			1		1	3		1		4	1	7		3	1	ш	4
Manufacturing - Discrete					1	6		5	2	5		14		2	3	Ш	7
Materials - Ceramics						8		3	2		1	7			2		4
Materials - Metals						5	1	3	6	1	4	8			4	Ш	5
Materials - Polymers			1			18	1	4	3	8	3	13			6	ш	10
Measurement Technology - Instrumentation	1	1	1		1	42	1	8	19	20	1	49		2	4	ш	15
Measurement Technology - Process Control	1	1	1			8	1	6	2	7	2	10			2	ш	4
Measurement Technology - SI Units	 _	1	1		1	7		1	3	7	2	11		2	-	$\vdash \vdash$	2
Nanotechnology	1	—				25	1	6	11	11	6	24		1	1	\vdash	15
Other Con Enforcement	+	-			1	2	1	2		1		3		1	1	\vdash	\vdash
Other - Law Enforcement	1		2			2		1	2	1	0	2	_	_	4	\vdash	
Telecommunications	1		2			14		6	2	8	2	15	_	2	4	\vdash	6
Transportation - Aerospace	1		1			6	4	7	2	2	1	9	_	2	3	\vdash	4
Transportation - Automotive	Т		3			11	1	/	7	5	2	19		1	2	1	6

Exhibit 12.27: Total MN Distribution (All Groups)

		Chemicals,		Electronics													
		Industrial		(Non-		Energy,		Manufac					Other -			Transpor	i
	Building	Biotech,	Defense &	semiconduct	Electronics	Power &		turing		Measureme	Nano-		Law	Softw	Teleco	tation -	i
Agriculture & Food	and Con-	Continuous	Homeland	or) and IT	(semiconduct	Environme	Healthc	(Discrete		nt	technolo		Enforcem	are	mmuni	Aerospa	
Processing	struction	Mfg	Security	Hardware	or)	nt	are)	Materials	Technology	gy	Other	ent	for IT	cations	ce	Total
5	23	22	35	52	52	27	77	32	40	91	36	1	2	33	18	7	553

